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THE UNIVERSITY OF ALBERTA

EDUCATIONAL COMPUTING ENVIRONMENTS: AN AUTOPOIETIC ORIENTATION

Ⓒ

BY

JACQUELINE ELIZABETH WARD ALLAN

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARITAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
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Daiyo Sawada
(Supervisor)

C. Chamberlin

Alton T. Olson

Date: June 22, 1988

to Gene, Rob and Beth

ABSTRACT

Six computing environments which focus on one or more of the computing applications of CAI, word processing, BASIC, and Logo provide the settings for the study. The experiential nature of the computing environment for the student and the role of the teacher are described within the orientation of the theory of Dissipative Structures and the theory of Autopoiesis. The nature of an autopoietic computing environment is discussed. A description of the author's personal involvement with computer implementation is included as an example of an autopoietic living system in a continual process of Becoming.

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TABLE OF CONTENTS

CHAPTER PAGE

I. INTRODUCTION.......... 1
PURPOSE OF THE STUDY.......... 4
QUESTIONS.......... 4
DESIGN OF THE STUDY.......... 4
DELIMITATIONS OF THE STUDY.......... 5
SIGNIFICANCE OF THE STUDY.......... 5

II. THEORETICAL ORIENTATION.......... 6
THEORY OF DISSIPATIVE STRUCTURES.......... 7
APPLICATION OF THEORY OF DISSIPATIVE STRUCTURES TO AND EDUCATIONAL SETTING.......... 9
THEORY OF AUTOPOIESIS 11
APPLICATION OF THE THEORY OF AUTOPOIESIS TO AN EDUCATIONAL SETTING.......... 16

III. METHODOLOGY.......... 18
THE SETTING.......... 20
THE INFORMANTS.......... 20

DATA COLLECTION 21
  Observation 21
  Interviews 22
DATA ANALYSIS 23

IV. **PART I - BACKGROUND TO THE STUDY: A PERSONAL HISTORY** 25
PART II - BACKGROUND TO THE STUDY: COMPUTER TECHNOLOGY 33

V. **FINDINGS OF THE STUDY** 40
HUNTER SCHOOL: ANDREW 42
  CAI - Social Studies 42
  CAI - Mathematics 43
  CAI - Problem Solving 44
  Word Processing 45
  General Comments 47
QUEENS SCHOOL: ANNE 50
  Math Centre - CAI drill and practice 50
  Computer Literacy - Programming in BASIC 52
J. P. HENLEY SCHOOL: RYAN 55
RIVERVIEW SCHOOL: BRENT AND SCOTT 59
  Brent 59
  Scott 61
EASTSIDE SCHOOL: BRYAN, CORY AND SUE 64
  Bryan 65

Cory.. 66

Sue.. 67

MAYRIDGE HEIGHTS SCHOOL: ELIZABETH AND AMANDA. 70

VI. CONCLUSION.. 75

NATURE OF COMPUTING ENVIRONMENTS............................... 75

CAI - Drill and practice.. 75

Students.. 75

Teachers... 77

CAI - Problem Solving.. 78

Students.. 78

Teachers... 78

Computer Literacy - Programming in BASIC.......................... 79

Students.. 79

Teachers... 79

Word processing... 81

Students.. 81

Teachers... 81

Logo.. 82

Students.. 82

Teachers... 84

THE AUTOPOIETIC COMPUTING ENVIRONMENT...................... 86

CONTINUATION OF MY PERSONAL HISTORY............................ 89

IMPLICATIONS BEYOND THE COMPUTING
ENVIRONMENT.. 93

SUGGESTIONS FOR FURTHER RESEARCH................................ 93

FIGURES.. 95

BIBLIOGRAPHY.. 96
APPENDIX.....GLOSSARY.. 99

CHAPTER ONE

INTRODUCTION

Computer technology has become pervasive throughout our society. Technological developments of the past decade have brought pressure to bear on our system of education and on the component members of that system to integrate computer technology into the community of the classroom. What knowledge, skills, and values will be required of our students in the future? As educators struggle with questions for which no one has the answers, implementation continues. In recent years, education has integrated technological changes (i.e., television, calculators) into the classroom with little disruption to the system. Will computer technology, also, slide comfortably into our schools or will it have a profound effect on how we organize our classrooms for learning?

The theory of dissipative structures (Prigogine & Stengers, 1984) and its application to education (Sawada & Caley, 1985) tells us that revolutionary change may result from chaotic situations. However, there is a tendency among systems to maintain the status quo. Should disruptions to the system be minor, the system will quickly return to a stable state. Television and calculators, for a time, caused minor disruptions to our system of education. But because the disruptions were minor, the system returned to a stable state without any significant change in its structure. The theory of dissipative structures provides an appropriate metaphor to aid description of observable behavior within computing environments.

The theory of autopoiesis (Maturana & Varela, 1980, 1987) and its application to education (Sawada & Pothier, 1988) provides a metaphor to aid description of activity which happens within the system but is not observable. For change to occur within the larger educational system, change must occur within the component members of that system. Each component member within the educational system is, in itself, a social system dependent for survival on its ability to maintain its identity and regenerate its basic organization. The structure of a system is a composite of its inherited biological characteristics and its ontogeny (structural adaptations). As living systems maintain their organization (autopoiesis), they may become perturbed by environmental or internal influences. The structure of the system determines what will become perturbational. Through recursive processes within the system, structural changes are made while the basic organization of the unity remains homeostatic. As change occurs within the component members of the classroom, recurrent coupling between component members of the classroom and other component members of the larger educational system with subsequent co-drifting may lead to change within the larger system of education. For example, the first microcomputers in our schools were scattered around the district, often the responsibility of the math teachers. Many of these teachers attended university and college courses and became involved in interest groups. As teachers shared their ideas about computer implementation, friendships emerged. These teachers often shared what they learned at meetings and classes with staff members in their schools. Through the efforts of teachers in one particular interest group, the Alberta Teachers' Association Computer Council was created, tying together teachers using computers throughout the province. Edmonton Public School Board established Microcomputing Services, constructed a centralized microlab and hired consultants. Alberta Education supported research, established the

Clearinghouse, prepared curriculum documents, and negotiated software prices. As teachers with different expertise explored and shared the possibilities for this technology in education, the use of computers broadened from its previous mathematical orientation to one in which computers are now being integrated into many areas of the curriculum. Change which took place among the component members (teachers) of the educational computing community led to change within the larger systems of education.

It was not by design but by simply being in the right place at the right time that I became involved in computer implementation. At times, computer technology created turmoil within my class. I was perturbed by my observations and my inner feelings. My students were exhibiting an enthusiasm toward this technology that I had previously only seen them show towards physical educational activities. I began to feel an excitement toward my job that I had not felt in many years. I began to examine my teaching practices, many of which I had not questioned in a long time. The introduction of computers into my classroom disrupted the normal pattern of activity and a different relationship between the component members (myself and my students) was emerging.

My research and subsequently this thesis spontaneously arose from my need to understand what was happening to my students and to me. The theories of dissipative structures and autopoiesis allowed me to glean personal meaning from my classroom experiences and my research observations and data. As I became involved with the data and the background literature, I came to believe that this thesis is simply the story of my own autopoiesis and by telling that story I hope to demonstrate the appropriateness of the theory of autopoiesis (Maturana & Varela, 1980, 1987) to an educational setting.

PURPOSE OF THE STUDY

The purpose of this study was to add meaning to my personal experiences of computer implementation and its effects beyond the computer setting.

QUESTIONS

The questions were not based on preconceived hypotheses but rather on the desire to determine the meaning of what was happening to students and teachers in four different computing environments; CAI, BASIC, word processing and Logo. The questions were:

(1) What was the experiential nature for the child in each of the four computing environments?

(2) What was the role of the teacher in each of the four computing environments?

(3) What was the nature of an autopoietic computing environment?

DESIGN OF THE STUDY

Selection of schools was based on the desire to observe the computing environments CAI, BASIC, word processing and Logo. Ethnographic methods were employed to gather the data through observations of students using computers and interviews with students and teachers. The data were analyzed for emerging themes and then reanalyzed within the orientation of the theories of dissipative structures and autopoiesis.

DELIMITATIONS OF THE STUDY

This study is delimited to six classrooms with grade five and six students as they participated in computer related activities: Hunter School, three teachers, one student; Queens School, one teacher, one student; J. P. Henley School, one teacher, one student, Riverview School, one teacher, two students; Eastside School, one teacher, three students; Mayridge Heights, one teacher, two students.

Data collection is delimited to transcripts of interviews with teachers and students and field notes of observations.

SIGNIFICANCE OF THE STUDY

Principals and teachers are feeling the pressure to implement computers into the schools, but few educators have expertise in computer technology. This study provides a description of one person's implementation of computer technology and offers a brief look into the lives of other teachers as they used computers with their students. Four different computing environments were examined as to how each supports the autopoiesis of the student. This information may be useful for educators as they make decisions regarding computer implementation.

Educators may also be introduced to a new metaphor with which to describe educational activities. If reading the study causes readers to be perturbed so that they question their use of technology or educational methodologies, then the study is significant. Generalizations cannot be made beyond the study, but perhaps this document can encourage third-order coupling and co-drifting (see Chapter Two).

CHAPTER TWO

THEORETICAL ORIENTATION

"Traditional" education finds its roots in Newtonian thinking which gave rise to the classical era in science: The world was seen as a composition of minute building blocks or atoms which combined to make up the physical universe. Atoms and their combinations were inert and their combination or separation, as well as their motion, was dependent upon an external force (e.g. gravity, pressure, adhesion, etc.). Within the Newtonian framework, nature was studied and mathematical formulae were developed to express, in symbolic form, the "laws of nature" (Doll, 1986a).

The metaphor developed that the world was a giant machine controlled by the "laws of nature" and that all parts of the machine, including man, were controlled by these laws. Basic to Newtonian thinking was the idea of reversibility--what comes together can also be separated. Newtonian thinkers searched for the facts to understand nature as they felt that should they understand the laws of nature it would be possible for them to predict the future and retrodict the past--a particular moment in time is the same whether it is in the past, present, or future "all other conditions remaining the same." In this system chance plays no part; there is no room for spontaneity (Doll, 1986b).

Our present educational system developed within a culture that was in the midst of an industrial revolution imbued by the ideas of Newton. Students are expected to learn basic "truths" as well as a tool kit of procedures which provide the basic skills and knowledge leading to an understanding of the "laws of nature". The thought prevails that whatever exists can be measured and related to the normal curve. Quantification has played an important role in evaluation of the learner and in research design. Science describes but does not participate in the universal laws of nature and the right of an individual to participate in describing these laws is highly restricted and reserved for those among us considered to be intellectually elite. Those happenings which do not coincide with the universal laws are considered "flukes" of nature and not worthy of serious study (Sawada & Caley, 1985; Doll, 1986b).

THEORY OF DISSIPATIVE STRUCTURES

Prigogine (1984) describes the Newtonian idea of science as a closed system and although some parts may work like machines, that is only a small part, and may not exist at all in reality. He attempts to point the direction of science away from stability, conformity, and control in a direction where uncertainty, disorganization, and instability are universal. Scientific phenomena to Prigogine are open systems, composed of subsystems, embedded in the culture from which they develop with ideas continually looping back and being reassessed by that culture. The subsystems are continually "fluctuating" and at times these subsystems can become so powerful that they destroy the organization of the system. At this point, a bifurcation point, the system will disintegrate or reorganize into a new system. These levels of organization are called dissipative structures. Prigogine believes we should turn our attention to the organization that can and does occur out of disorganization. "Classical science, the mythical science of a simple, passive world, belongs to the past, killed not by philosophical criticism or empiricist resignation but by the internal development of science itself" (Prigogine & Stengers, 1984, p.55).

Prigogine (1984) bases his universal idea of science on the Second Law of Thermodynamics which states that within nature there is a universal tendency toward degradation of mechanical energy, entropy. The world is no longer described as a machine in which energy is conserved and transformed through a cycle returning to its original state but as a machine in which transformations are irreversible. Within this metaphor, the giant machine is running down but Prigogine and Stengers are optimistic that entropy is not just a downward slide but, with the right conditions, can spontaneously create new and higher levels of order. "Man's power to control his universe may be much greater than ever imagined" (Dyson in Prigogine & Stengers, 1984, p. 117).

Prigogine and Stengers describe three thermodynamic states for open systems: (1) those that are at equilibrium within their environment, (2) those near-equilibrium within their environment, and (3) those far-from-equilibrium within their environment. Within each of the three states reactions can be enhanced with catalysts or through cross-catalytic or auto-catalytic action.

(1) An equilibrium state exists when the forward and reverse actions of the molecules equal one another and there is no further variation in the composition of the substance. Entropy production is zero. There is an evolutionary movement toward equilibrium and when attained the initial conditions are forgotten making this state irreversible.

(2) A near-equilibrium state is one within which interaction with the environment causes the reactions of the molecules to be linear and predictable. It is described as a reciprocity relationship between the molecules of the different substances and in which there is minimum entropy. It moves as close to equilibrium as its boundary conditions in the environment will allow.

(3) A far-from-equilibrium state is a high entropy state in which forces in the environment cause the molecules to go beyond linear reactions to reactions in which spontaneous fluctuations occur. When this happens, the organization of the system dissipates (becomes chaotic) and there can be evolution toward a new and qualitatively different organization. The system at this time is at the bifurcation point and the structure to be evolved cannot be predicted. The system either moves forward to new order or disintegrates and dies. The probability of a system being far-from-equilibrium is low, but it does occur. Once the new state is reached, the system becomes deterministic and relatively stable (near-equilibrium) until another bifurcation point is reached. Toffler provides us with a societal example of these three states:

> Imagine a primitive tribe. If its birthrate and death rate are equal, the size of the population remains stable. Assuming adequate food and other resources, the tribe forms part of a local system in ecological equilibrium.
>
> Now increase the birthrate. A few additional births (without an equivalent number of deaths) might have little effect. The system may move to a near-equilibrial state. Nothing much happens. It takes a big jolt to produce big consequences in systems that are in equilibrial or near-equilibrial states.
>
> But if the birthrate should suddenly soar, the system is pushed into a far-from-equilibrium condition, and here non-linear relationships prevail. In this state, systems do strange things. They become inordinately sensitive to external influences. Small inputs yield huge, startling effects. The entire system may reorganize itself in ways that strike us as bizarre (Toffler in Forward of Prigogine & Stengers, 1984, p. xvi).

APPLICATION OF THEORY OF DISSIPATIVE STRUCTURES TO AN EDUCATIONAL SETTING

Sawada and Caley (1985) present the theory of dissipative structures (Prigogine & Stengers, 1984) as a new metaphor for education. If we look at one subsystem within the educational system, that of the traditional classroom, we would see members of that classroom, teacher and students, performing their roles where the teacher teaches and the student learns. Everything runs smoothly with information presented in a top-down manner to enthusiastic students who demonstrate "knowledge" and proceed through the levels according to a highly structured system of checks and balances. This classroom, highly prized within the traditional school setting, is at equilibrium.

More frequently, classrooms within the traditional structure would be near-equilibrium as teachers "cope" with problems and changes that tend to disrupt the delicate balance. Educational innovations such as discovery learning, new math, or enterprise tend to disturb the equilibrium of the classroom. Although these educational innovations were exciting at the time, they have contributed minimally to the change of the overall educational structure because the system is dominated by powerful forces returning it to equilibrium (Sawada & Caley, 1985; Doll, 1986).

Occasionally something will happen to take the system far-from-equilibrium. To Prigogine the only state which allows for spontaneous reorganization of the system is that which is far-from-equilibrium. The system responds in a non-linear manner to factors creating a state of turbulence or chaos. At some point, called a bifurcation point, reorganization can occur. The form of the reorganization is qualitatively different from the initiating state and cannot be predicted. Once new order has emerged the system returns to a near-equilibrium or deterministic state until the next bifurcation point. An education example of a qualitatively different state is given by Doll (1986) who says it is time to move from a "measured curriculum" to a "transformative curriculum". This new curriculum would focus on the qualitative changes of both teachers and students "as they engage in the curriculum: here curriculum is being considered as a process of engagement not as a 'course to be run'" (p. 31-32).

In far-from-equilibrium situations, the participation of a role model in the process of education functions as a catalyst in the "Becoming" of students. At first the teacher acts in a cross-catalytic manner, but as the students progress they can be auto-catalytic. "This is a powerful metaphor. It demands that teachers must continually Become as they guide their students through the process of Becoming" (Sawada & Caley, 1985, p. 17).

THEORY OF AUTOPOIESIS

Maturana and Varela (1980) through their biological studies believe it is not sufficient to study living systems using input/output or cause/effect models. Instead, they should be looked at as closed autonomous systems which produce or create themselves and are defined by the actions that produce them not by the external environment. The name "autopoiesis", derived from autonomous, and "poiesis", meaning self-creation or self-production, was created by Maturana to provide a new word, without history or connotative diversity, with which to discuss living systems.

The survival of living systems, from unicellular organisms to metacellular organisms and social systems depends on their ability to maintain their organization. "They differ from each other in their structure, but they are alike in their organization" (Maturana & Varela, 1987, p.47). In an ever changing environment, autopoietic systems occupy a niche consisting of all interactions through which they maintain their identity and reproduce their basic organization. They receive recursive feedback internally by responding, in accordance with invariant qualities that maintain the organization, to perturbations which can originate in either the external environment or from within the system. It is the recursion or circularity that maintains the order and in turn the circularity or recursion is maintained by the system.

Adaptation occurs when the living system makes structural transformations while maintaining or conserving its identity. These changes become evolutionary through the organism's ability to reproduce. The living system changes structurally through "coupling" with its environment. "Structural coupling is always mutual; both organism and environment undergo transformation" (Maturana & Varela, 1987, p. 102).

> ...a conservation of autopoiesis and conservation of adaptation are necessary conditions for the existence of living beings; the ontogenic structural change of a living being in an environment always occurs as a structural drift congruent with the structural drift of the environment (Maturana & Varela, 1987, p. 103).

Maturana and Varela (1987) describe three orders of structural coupling:

(1) first-order coupling; a unicellular organism couples with its environment,

(2) second-order coupling; a metacellular organism, which contains within its structure autonomous living systems, couples with the environment as a distinct unit,

(3) third-order coupling or social systems. "When two or more organisms interact recurrently, they generate a social coupling" (Maturana & Varela, 1987, p. 206). Communicative behaviors within a domain of ontogenic structural coupling produce a linguistic domain. Through structural coupling within the linguistic domain, human beings have developed language.

Language developed through third-order coupling and it is through language that third-order coupling is recursively maintained.

As living systems couple with the environment, a "natural drift" occurs. Both the living system and the environment vary independently but change structurally in response to mutual perturbations and as long as the living system maintains reproduction, the drift continues. To illustrate natural drift, Maturana and Varela (1987) use the example of drops of water sprinkled at the top of a hill. As the drops move down the hill they repeatedly join together with and separate from other drops. When they join together with other drops "co-drifting" occurs. Changes within the drop of water are congruent with changes to the surface of the hill.

Perturbations are those factors which disrupt the equilibrium of the living system. When the perturbation activates the system, a recursive process occurs in which the system deals with the perturbation in relation to its own autopoiesis. Perturbations may be generated by the system itself. It is through this recursive activity that the system is driven further from equilibrium and the opportunity exists for a new order or structure to develop.

There is a distinct difference between perturbations and inputs. Inputs must be generated from the environment and the action that the system takes in response to an input is compliance where the system is left unchanged. Response to an input is an output which is an allopoietic action. What is difficult is that the responses to an input or to a perturbation may appear be identical to the observer but these responses are qualitatively different to the living system.

As autopoiesis occurs within a system, some qualities are unaffected by perturbations. These qualities which the system chooses to protect and support are the essence of the system and are known as the invariant qualities.

Man is an autopoietic system. In the words of Maturana,

> Man is a deterministic and relativistic self-referring autonomous system whose life acquires its peculiar dimension through self-consciousness; ethic and morality arise as commentaries that he makes on his behavior through self-observation. He lives in a continuously changing domain of descriptions that he generates through recursive interactions with that domain, and which has no other constant element in its historical transformation than his maintained identity as an interacting system. That is, man changes and lives in a changing frame of reference in a world continuously created and transformed by him. Successful interactions directly or indirectly subservient to the maintenance of his living organization constitute his only final source of reference for valid behavior within the domain of descriptions, and hence, for truth; but since living systems are self-referential systems, any final frame of reference is necessarily relative. Accordingly, no absolute system of values is possible and all truth and falsehood in the cultural domain are necessarily relative (Maturana in Maturana & Varela, 1980, p. 57).

When autopoietic systems recurrently interact natural social systems develop. These are the result of third-order coupling (Maturana & Varela, 1987). The existence of an autopoietic social system relies on the continued autopoiesis of the members and, in order that the nature of autopoiesis in the larger social system be understood, it is necessary to understand the autopoiesis of the individuals from which that social system developed. Humans participate in social activities with others and enter into the domain of others to the extent that their personal identity or autopoiesis is preserved. Membership is maintained in many social systems at one time.

Membership is also maintained in a hierarchial social structure. Beer (Preface to Maturana and Varela, 1980) contends that any cohesive social institution is an autopoietic system because it survives and that all social systems are embedded in larger social institutions. In order that these larger social institutions be autopoietic, they may reduce the autopoiesis of the embedded systems. Although social institutions have developed naturally their continued survival may depend on the rules and regulations which have not developed naturally from the embedded systems. Human social systems can be described as "mixtures of deliberate arrangements of man-planner-designer, interacting with complex, spontaneously emerging orders" (Zeleny, 1985, p. 118). Once established, social systems and institutions are essentially conservative and resistant to change with change occurring only following change among the component members.

Through successful autopoiesis individuals attain knowledge but that knowledge is personal and private, existing entirely within the domain of the individual. Learning is a continuous process of Becoming, with behavioral transformations taking place in response to continuous changing and synthesizing of the nervous system. These transformations are spontaneously generated and cannot be determined in advance.

> Learning as a process consists in transformation through experience of the behavior of an organism in a manner that is directly or indirectly subservient to the maintenance of its basic circularity. Due to the state determined organization of the living system in general, and of the nervous system in particular, this transformation is an historical process such that each mode of behavior constitutes the basis over which a new behavior develops, either through changes in the possible states that may arise in it as a result of an interaction, or through changes in the transition rules from state to state. The organism is thus in a continuous process of becoming that is specified through an endless sequence of interactions with independent entities that select its changes of state but do not specify them (Maturana in Maturana & Varela, 1980, p.5).

If autopoietic systems are closed, how does this relate to Prigogine's theory of dissipative structures which describes three stages of open systems? Prigogine's open systems are described as such because they find their momentum or energy from environmental forces. Autopoietic systems are closed in that they are autonomous and self preserving but they can be at equilibrium, near-equilibrium, or far-from-equilibrium and, therefore, open, in relation to the environment. An autopoietic system that finds itself far-from-equilibrium with the environment may choose to make changes in order to maintain the invariance which is the autopoiesis of the system.

In an attempt to bring dissipative structure theory together with autopoiesis, general systems theory in psychotherapy describes "flux equilibrium" as the selected opening and closing of boundaries. Living systems have permeable boundaries which open to receive energy or close to keep out excessive input. When the system is closed, it receives information (input) and assimilates it within the internal structure of the system. When the system is open it receives energy (perturbations) and makes accommodations to that energy within the system. Opening and closing are not good or bad but complementary processes whereby the system survives and grows (Durkin, 1981).

APPLICATION OF THE THEORY OF AUTOPOIESIS TO AN EDUCATIONAL SETTING

Sawada and Pothier (1988) feel that autopoiesis can serve as a theoretical structure through which to describe educational settings. If we are in a constant state of Becoming, methods of analysis of cause/effect relationships are inappropriate. Recursion is a nonlinear process incorporating multiple horizontal actions within the closed living system. Students and teachers are subsystems within the nested hierarchial social systems of education. If the classroom is a spontaneous social system which assists and supports the learning of students, (i.e., the atmosphere of that classroom is such that learning is encouraged) then the learning will, in turn, support and enhance the atmosphere of the classroom. In this classroom the basic circularity enhances the autopoiesis of all members.

To maintain the autopoiesis of larger more removed social systems, controls may develop which inhibit the autopoiesis of the individual members from which that social system was formed. These higher order social systems may have originated spontaneously but structural changes within have shifted the autopoietic activities toward maintenance of the larger system rather than maintaining the autopoiesis of the individual members or members of embedded subsystems. When this occurs, members of one system may view another system as allopoietic. For example, students in a classroom where the teacher attends to curriculum, teaching, and controlling behavior rather than learning may respond in allopoietic ways such as "playing the game", striving for grades, and so on.

Autopoiesis when used in conjunction with the theory of dissipative structures focuses attention on the underlying and often hidden actions which control how the system will react when faced with perturbations from the environment and from within the system itself. The theories of autopoiesis and dissipative structures will serve as an orientation from which to analyze my observations of six computing environments.

CHAPTER THREE

METHODOLOGY

The problem of this study evolved through my experiences in the classroom and the design of the process by which information was to be gathered developed from the questions to be answered. The process used satisfies the four criteria of good naturalistic educational research described by Hamilton (1983) who contends that recognition and attention be paid to; (1) the social interactions between teachers and students, (2) learning as a continuous interactive process, (3) classrooms being nested in other social organizations, and (4) thoughts, feelings, attitudes, and perceptions of teachers and students as valuable sources of data in addition to observable actions.

Ethnographic research is a recursive process. Spradley (1979) identifies five ethnographic research tasks in sequence but indicates that they must all go on at the same time. They are (1) selecting a problem, (2) collecting cultural data, (3) analyzing cultural data, (4) formulating ethnographic hypotheses, and (5) writing the ethnography. "Before going on to any new phase of research, the ethnographer must go back and collect more cultural data, analyze it, formulate new hypotheses, and then repeat these stages over and over again" (p. 94).

In studying a computer environment, one attempts to put a stop-action on a system that is continually evolving. What the observer sees is a reflection of the recursive changes that take place during autopoiesis. Descriptions based on these reflections can indefinitely increase the complexity of the observer's cognitive domain (Maturana in Maturana & Varela, 1984). Through observation the researcher sees that part of the niche (class of interactions that can be entered into without losing identity) which intersects with the environment and which is compatible with the cognitive domain of the observer.

An observer may describe a system as "allopoietic" or as being created or produced by others because of an incompatibility between the observed system and the domain of the observer. Allopoietic systems exist only in the eyes of the observer. If a biological system is allopoietic it dies. Social systems that inhibit the autopoiesis of the component members are oppressive. Systems which are forced to participate in larger systems can feign certain actions in compliance with the larger system, but when the control is removed the playacting stops. Observations are not sufficient to distinguish between autopoietic and allopoietic acts as the observed behavior in these situations may be identical. The research must attempt to view the behavior within the autopoiesis of the system.

When the observer attempts to transfer descriptions to others, s/he should be aware that language has evolved naturally through autopoiesis to reveal one's own cognitive domain and was not designed for the purpose of transferring information. Knowledge can only be transferred to the extent that the listener understands and accepts that knowledge into his/her life space. Thought processes are encoded within the domain of the author and decoded within the domain of the reader. Communication is largely assimilation of input within closed boundaries.

Should members share a local enclave their boundaries open and conversations occur. A conversation is a series of recursive interactions which serve as perturbations to the participants (Sawada & Olson, in preparation) driving them to a state far-from-equilibrium.

Knowledge evolves naturally within man. Analysis will not teach us about the real world but man's descriptions of his world can serve as perturbations to the autopoiesis of himself and of others.

THE SETTING

Thirteen elementary schools were initially visited to get an idea of the types of computer activities occurring within each school. Four categories emerged: computer assisted instruction, word processing, programming in BASIC, and programming in Logo. Generally schools designed their Computer Literacy program around at least two of these categories. Six computer settings were selected which would provide a variety of student experiences to observe.

Three types of computers were being used. In four of the six settings, computers were housed in labs. In one setting a single computer remained in the classroom full time, and in another, the computers were mounted on carts and moved into the classroom at specified times. The numbers of computers ranged from one in the class to twenty-two in a lab setting. By selecting six computing environments to study I was not able to study indepth any one particular environment. But to answer my questions, I felt it was necessary to observe a variety of settings.

THE INFORMANTS

The students who I met, observed, and talked to about their computer activities were sometimes selected by the teacher, based on their ability to engage freely in conversation; or at other times the student just happened to be at the computer when the observation took place. Ability levels ranged from students who the teacher considered "slow" to those attending special enrichment classes. The study was limited to students in grades five or six. At least one student and often several in each of the six settings were observed at the computer and interviewed. This report documents the story of at least one student in each of the six settings.

Because the research questions presented were based on my experiences with computers in the classroom, I felt it was important that the teachers in my study were comfortable with the technology and had experience using computers with their students. Observations were made of the class in action. In five of the schools, the computer activity in which the child engaged was under the direction of a single teacher. In the sixth school three teachers were involved with the computer activities of the child.

DATA COLLECTION

OBSERVATION

As a researcher, I was aware that my observations and interpretations were flavored by my own cognitive domain. By being a member of the computing teacher community, I was likely unable to distinguish these computing environments as clearly as an outsider could. "But work in your own society teaches you how subtle differences can be, and also shows you new depths of interpretation that you bring in as a comember" (Agar, 1980, p. 196). Chapter Four provides a reflection of my experiences which contributed to the evolution of this study. Hopefully I have confronted my biases.

Data for this study was collected during May and June of 1984. A preliminary visit was made to each school to familiarize myself with the setting, inform teachers of the project and to establish times for observations and interviews. These visits were informal and served as initial entries into the field, establishing a relaxed and comfortable relationship with the teacher.

I became a participant observer of students as they engaged in computer activities. I did at times audiotape these sessions but generally taping did not occur because either the class was too noisy or the student preferred not to engage in much discussion. I was sensitive to the fact that some students viewed my questions as interruptions and I recognized that hands-on computer time was precious as a small number of computers were shared by many children. I attempted to assume the role of a teacher who had no experience with computers and was trying to make a decision about what I should do with my own class the following year. This role was accepted by students who likely believed that most teachers did not have much computer knowledge. However, it was difficult to remain true to this role and not provide assistance to students.

INTERVIEWS

Interviews with students followed as soon as possible after the classroom observation. The observation provided a framework for questions which probed more deeply into the experiences the student had had with computer technology. The research questions provided the umbrella for question formation but specific questions also arose spontaneously from the descriptions the students offered (conversation as a spontaneous social system).

Interviews with teachers were conducted following the interviews with the students. The teachers generally exhibited pride in their computer classes and the accomplishments of their students and were willing to share these with me. During these interviews probing questions were asked based on the in-class observations and the interviews with the students. My personal background with computers was known to the teachers and I was acquainted with some of the teachers in the study through involvement in computer groups or university courses. All interviews were audiotaped.

DATA ANALYSIS

Primary data analysis began while still in the field with the listening and transcribing of audiotapes of student interviews. The observations and interviews with the students provided the structure for the development of questions for the teacher interviews. The teacher interview provided background information on students, clarified a student response, or further revealed the nature of the computer environment.

After interviews were completed, second-order data analysis commenced. During this analysis all data were recursed upon with the intent of bringing forth themes or invariants. Triangulation (Glaser and Strauss, 1967) provided a process for recursively revisiting the observations, field notes, photographs, interviews with students, and interviews with teachers. The themes were then looked at in reference to the problems which initiated the study.

Other teachers were having similar experiences to the ones to be described in Chapter Four, but I still felt inadequate in describing what I was observing. Prigogine's theory of dissipative structures and Maturana and

Varela's theory of autopoiesis provided a structure for explaining what I had learned during my study. The data were once again reviewed, this time analyzed within the orientation of these two theories. A second reader who was versed in these theories added credibility to the study by supporting and adding to the analysis (Glazer, 1972).

CHAPTER FOUR - PART I

BACKGROUND TO THE STUDY: A PERSONAL HISTORY

Within the theoretical orientation of autopoiesis, I am a living system, opening my boundaries to perturbations or closing my boundaries to inputs, in the continual process of Becoming. The choice of research questions to be addressed in this thesis are part of my autopoiesis. As a researcher, I have reflected on my experiences and recorded a chronological report to provide the reader with a sketch of a series of perturbations which have recurringly pushed me far-from-equilibrium. By observing myself and documenting my story, I feel I have come to grips with my biases. Throughout my story, interpretations of the reflections are enclosed in square brackets.

In June of 1981, I was called to a meeting with the vice-principal and principal of my school. The school had some money remaining in the budget and I was asked, "If you had a microcomputer could you do something with it?" I was stunned. There had been some talk of computers in the schools but to me they had a mystical quality. I had no idea what was possible or would be expected of me. I remember feeling very anxious, so anxious, that I went back to them within a day or two and asked exactly what they did expect. I had all sorts of visions of having to learn about this new technology and teach not only the students but also the staff. I would have to go on my own without curriculum guides or expert consultants. I was scared and felt that I might not be able to handle this but they assured me that whatever I did and felt comfortable with would be all right with them. With that assurance and the fact that I believed they had shown confidence in my ability by choosing me, I nervously accepted the challenge.

Although it is impossible to recall the entire array of thoughts that passed through my mind, I do remember considering the feelings of my family related to the time commitment that would be required. In retrospect I must have been somewhat unhappy with teaching because I felt if I became knowledgeable in this area the door to a career change may open. I felt computer technology was going to have a profound impact on society and, therefore, on education. As a part-time teacher, I was concerned with improving my chance of getting a full-time position. My ego, too, was given a boost when the administration asked me to become involved.

[As a living system involved in my own autopoiesis, the thoughts above provide reflections of the recursive thinking in which I engaged as I dialogued with myself dealing with the anxiety that typically accompanies a new venture. As recursion draws on all life's experiential knowledge much of the cognitive activity that occurred did not take the form of reflection and was hidden from me at the time. Also, with the passage of time, some of what was reflected is not remembered. The acceptance of this new responsibility to take a leadership role in computer technology for my school was a bifurcation point in a far-from-equilibrium system. I was open to receive perturbations and I recognized that accommodations made within myself would affect me and other comembers of social systems such as my family, my classroom, and my school. I was hopeful that changes made to my teaching career would be significant.]

I spent the month of August with the new school computer at home on my dining room table poring over the manuals. I remember struggling for several days trying to get the machine to accept my blank disk but not having figured out what "initializing the disk" really meant. Perhaps the most anxious time was taking the components out of the boxes and assembling them for the first time. I was sure that I would do something wrong and wreck this "phenomenally" expensive piece of equipment. By the time school started I could write two or three line BASIC programs, access programs on the DOS disk and enter student names and beginning levels on computer assisted/managed mathematics software. Hooray I had found a use for the computer - it would take over the tedious chore of drill in mathematics and the computer would provide motivation through its uniqueness, positive reinforcement, and colorful graphics. I was quite convinced that students would learn to program and would eventually program their own games. I was also going to teach the students about computers so they could go into junior high and high school armed with knowledge of this wonderful new technology.

[Having survived the trauma associated with becoming involved with computer technology, things settled down to a more "normal" state (return to near-equilibrium state). As I began to learn a little about computers I recursed into the future to anticipate ways of incorporating this technology into the classroom. My implementation plan developed from recursion with my "knowledge" of educational practices, based on a fairly traditional background, and my rather unimaginative visions of the future.]

September was exciting for both the students and myself. My math class began using mathematics software and many "oohs" and "aahs" were heard as they worked their way through the drills. They were very motivated and competitions quickly sprang up between and among students to see what level they could attain. Students asked to stay in at recess and after school. I felt alone being the only teacher in my school involved with computers. Few teachers in my school registered much interest. I noticed an ad in the Edmonton Public Schools Bulletin for a meeting to take place at which a teacher would present what she was doing with her students regarding computer literacy. Off I went and tried to be inconspicuous, afraid that someone would ask me a question and my ignorance would be exposed. I assumed that all these people had computer backgrounds and that I was encroaching upon their territory. I understood some of what she said and when the presentation was complete several teachers went up and spoke to the teacher personally. I hung back again but I did ask another teacher how one could become aware of presentations of this type and I was eventually introduced to the presenting teacher.

[This may have been a turning point or a bifurcation point for me because I felt that I had stuck my neck way out. When I revealed to the presenting teacher how little I knew and how much I wanted to learn, I received some positive comments in support of my efforts. That teacher served as a catalyst to push me further from equilibrium. Had she not had time or not shown some interest in me, I may have moved back toward a point of equilibrium. I became involved in meetings of this type and was astonished to find out that many of the teachers attending were similar to me in their limited knowledge of computers. Emerging here was the beginning of a natural social system. The autopoiesis of the individual subsystems (teachers) received support through the formation of interest groups (higher order social systems). These interest groups were spontaneously generated by the subsystem with the autopoiesis of the interest group being subservient to the autopoiesis of the individual teachers who attended.]

At school the computer continued to be an exciting addition to the program and we expanded to three computers. Mathematics CAI continued and students began programming in a small way. A workbook approach was used with students inputting short BASIC programs and predicting what would happen. Modifications were made to these programs in an effort of solve problems presented in the workbook. Word processing was attempted and, although it was an enjoyable experience, the lack of hardware, limitations of the hardware (inability of the computer to display text in lower case), and the clumsy nature of the software provided little opportunity for it to contribute to student writing development. Although a computer literacy curriculum was not yet published by Alberta Education, it seemed appropriate to have students learn about computers so they would be better prepared for a future in which computers would serve an important role. While three students were entering data on the computers the rest of the class engaged in activities through which they would learn about computers. Such topics as the history of computers, computers in the workplace, binary numbers, and computers of the future were explored.

Student interest was high and what was intriguing to me was that the computer seemed to envelop students of all ability levels and even those who were "turned off" by other subject areas. Small groups formed around the computer as students worked together to solve problems. Students at their desks were very aware of what other students were doing at the computer and lessons would often be interrupted by students offering assistance to whoever was at the computer. I was only about two lessons ahead of them and had such little understanding of what I was doing that I rarely could explain why things happened as they did. I was no longer the authority but was sharing a learning experience with my students. It was exciting to share with a child a process for problem solving. In the past I had observed children solving problems but because I knew, or was expected to know, the solution I had rarely shared that space with a child.

[A new relationship between students as well as between teacher and students was emerging. In this relationship, the teacher served as a catalyst in the autopoiesis of the child through participation in and modelling of problem-solving behavior. Students within the class were cross-catalytic to one another. This natural social system supported the autopoiesis of the individuals (teacher and students).]

Although interest level was high and students genuinely wanted to learn about the computers, I was perturbed by their lack of understanding and inability to work independently when they went to the computer. It didn't seem to matter how many times I explained things to the class when they went to the computer most didn't know what they were doing. I wondered why I was wasting my breath but I did start asking myself if this was unique to computers or did the students also retain so little from other lessons!

[Recursion within the computer framework produced perturbations within noncomputer lessons. My experience within the traditional setting had been that motivation for learning was the responsibility of the teacher and where students did not respond, the fault fell on the shoulders of the teacher. But here, students were already motivated to learn and still my lecturing methodology seemed ineffectual.]

The school term ended with me enrolled in a BASIC programming course at summer session at the University of Alberta. Again I felt terror. I had convinced myself that all the people taking the course were mathematics or high school teachers and that I would fail miserably but I talked myself into taking the course because I needed it to help the kids. I met and became friendly with another woman (there were not many) in the class and thoroughly enjoyed both lectures and labs.

[Another bifurcation point occurred with respect to grades for the course. Because I lacked confidence in my ability to learn about computer technology, the grade I received was extremely important. Had I not done well on this, my first course in fourteen years, I may have closed my boundaries and moved toward a state of equilibrium. With closed boundaries, I would not have pursued further courses at the university and most certainly would not have decided to enter the Master's program. I see here the power of grades to influence my boundaries and encourage or discourage further learning. I wondered if it was the same for my students.]

Toward the end of that school year, an impromptu visit of a professor from the Faculty of Education resulted in his submission of a proposal to study, at my school, computer assisted instruction in mathematics. Student achievement in mathematics, student attitudes toward mathematics and technology, and teacher reactions to implementation were the focus of the study. When the 1982 - 83 school year commenced, I was the inschool resource person for the research project funded by Alberta Education (1983).

[The door had opened and I now was working full time with part of my salary funded by the project.]

The computers, now numbering five, were spread out throughout the school with students from grades two to six engaged in approximately ten minutes of computer drill in mathematics per day. My role changed to one of acquiring hardware, software, and instructing teachers in its use. I observed the data collection, analysis, and writing of the research report and some of the mystique of what goes on during research was wiped away.

[This research project provided catalytic action and pushed me further from equilibrium once more. A rather hazy decision to pursue further study at the university came into view and I applied for a sabbatical. It's interesting to note here that during the following year few teachers at the school continued to use the computers for daily practice. The computer was once again used as a reward for those students who had completed their work. The project had served as an input to teachers with information being assimilated but not becoming perturbational. The system returned to equilibrium.]

During this, my second year with computers, I took another BASIC course at the university and although I enjoyed the challenge of creating educational software I realized that elementary students were most certainly not going to create arcade type games. A friend introduced me to Logo and I became intrigued by the philosophy of Papert. I began having my students explore Logo. I was impressed by what I observed. Students assumed a new independence. Once they had a basic understanding of the primitives to produce screen graphics, they ventured out on their own. Students still consulted me when difficulties arose but now my advice or suggestions were at times accepted and at times rejected and yet the problems were being solved to the satisfaction of the students. The students took control. I felt that "something" was happening because of the introduction of first computers and then Logo into my class. "Something" was happening to the students but "something" was also happening to me.

[Through self-reflection, I began questioning the traditional teaching style I had clung to throughout the years. Was my role as a teacher to give knowledge or to facilitate the child's learning? I questioned whether the computer application of drill and practice, supported by the research project, was one which I wanted to support. Were electronic worksheets the best way to use computers in schools? The philosophy of Logo (see Chapter Four, Part II) plus my classroom experiences provided energy for me to engage in recursive thinking about computer usage. I wondered if other teachers shared similar thoughts and experiences. The research questions of this study evolved from these conversations I had with myself.]

CHAPTER FOUR - PART II

BACKGROUND TO THE STUDY: COMPUTER TECHNOLOGY

In 1977 the first microcomputers appeared on the market and since that time we have seen a rapid movement toward implementation of microcomputers into the schools in two basic ways; (1) students learning about computers and (2) students learning with computers. Much has been written about what students should learn about computers (Moursund, 1981, Leuhrmann, 1982). This area of study has become known as "Computer Literacy". In Alberta a computer literacy curriculum was published in 1983 emphasizing, at the elementary level, awareness of computer technology. The recommended topics were; "(1) How computers do their work, (2) How to use a computer, (3) How to make computers work for you, (4) How computers are used and what they can do for you, and (5) How computers affect our society" (Curriculum Guide for Elementary Computer Literacy, 1983, p. 8). BASIC (Beginner's All-purpose Symbolic Instruction Code) was the programming language with which most microcomputers came equipped. Many educators, as part of their Computer Literacy program, introduced BASIC programming to their students.

In recent years, the focus of the elementary computer program has turned from one of computer literacy to one of integration of the computer into the curriculum (Savill, 1986). Educators recognized the value of using computers as part of the curriculum to assist in educating the child. Probably the most widespread use of the computer in the elementary school was and continues to be computer assisted instruction (CAI). As hardware capabilities have improved, so too has the quality of software. CAI has acceptance among educators as an aid to student learning. Research reveals some interesting results beyond academic achievement. One study done in Israel reported that disadvantaged elementary students using CAI for mathematics attained higher scores on achievement tests and had more positive perceptions of school life (Mavarech & Rich, 1985). Another study found that CAI experiences in mathematics and reading over a two year period developed an improved attitude in the area of academic self-confidence, especially with special education students (Griswold, 1984). Johnson & Johnson (1985) report,

> Cooperative learning with computers (compared with competing with others or working independently at the computer) promotes more and better work, more successful problem solving, and higher performance on factual recognition, application and problem-solving (Johnson & Johnson, 1985, p. 11).

In the same article Johnson and Johnson also indicate that cooperative computer learning has an especially positive impact on females.

More recently, computer literacy has begun to be replaced by the teaching of productivity tools such as word processing, data bases, spreadsheets and graphics software. What better way to prepare students for the future than to have them use the power of a computer to more accurately and quickly produce jobs previously done painstakingly by hand? Productivity software has been effectively used to integrate computer technology into the curriculum. Teachers can create a data base, spreadsheet, or graphics design for students to interpret or students can be asked to use the software in a creative problem solving context (Schiffman, 1986).

Word processing has been used to have students develop skills and positive attitudes toward writing. Bank Street College of Education conducted a study that revealed students could "assimilate the technology and apply it to their model of composing" (Kane, 1983, p.22). Jacobi (1986) reported positive results in terms of attitude and behaviors of special education students but testing failed to produce evidence of improved writing skills. This result is not surprising considering the learning difficulties of the students, their limited keyboarding skills and the time devoted to the study. Christine Adams (1985) found when she taught composition to high school students using a word processor that too much time was lost on functional problems with the computer. Donald Graves speaks positively but cautiously about word processing. "I think marvelous things can be done with the computer as a word processor - if it's in the hands of someone who really knows writing" (Green, 1984).

Papert (1980) envisions a society in which computers enhance cognition and humanize society. He and his team workers at the Artificial Intelligence Laboratory and Laboratory for Computer Science at Massachusetts Institute of Technology developed Logo, a programming language for use with children, which he hopes will serve as a model from which will "grow a new education culture" (p.209). Papert sees a learning environment in which children will learn, using computer technology, powerful ideas of science naturally much as they learn to talk.

Papert, who studied with Jean Piaget for five years before going to MIT, was influenced by Piaget's study of genetic epistemology. "Piaget's epistemology is concerned not with the validity of knowledge but with its origin and growth" (Papert, 1980, p.163). Knowledge develops from within as the individual engages in making sense of the world. Children develop theories, sometimes considered incorrect within the adult world, which provide an explanation of the world within the cognitive domain of the child. Traditional education tends to ignore this theorizing of children but Papert believes that when children theorize, they "flex their cognitive muscles" and the theories form a framework on which to build further theories. By fashioning learning environments on the discipline rather than on the child's spontaneous development, traditional education risks intimidating children and making them feel incompetent (allopoietic act) when they are unable to understand adult theories. Through participation in a "microworld" (niche), children will learn naturally by relating what is new to something they already know and then make it their own to play with or build something new. Even during the initial introduction of Logo the syntonic nature of the language encourages students to use knowledge of their body to "talk" to the turtle.

Logo is itself a "microworld" but it can also be used by creative individuals, teachers and students, to fashion other "microworlds" within which the child can explore and learn. It could be used to teach traditional curriculum content, but Papert (1980) sees it as a "vehicle for Piagetian learning" or "learning without curriculum" (p.31). Learning in a microworld without curriculum does not mean that children will simply be left on their own but, instead of all students being taught in the same structured sequential manner, they will be allowed the freedom to explore within the self-created boundaries of the microworld.

In Papert's microworld, students take over control of their own learning and in doing so the role of the teacher drastically changes. Much less time will be spent on keeping records and grades and much more on collaborative learning. A new relationship between child and teacher emerges as the child realizes that the teacher is a learner too and that we all learn from our mistakes. Traditionally the teacher and student work as separate systems and attempts at collaborative situations are usually theatrical because the material was already known and understood by the teacher, but in the Logo environment teacher and child work together as one system, each contributing, thinking out loud and sharing in the problem-solving process - "the teacher does not have to pretend not to know" (Papert, 1980, p.115).

Emihovich and Miller (1986) contend that where positive outcomes have resulted from the teaching of Logo it has been not because of the Logo language but because of the process of instruction or the type of discourse in which teachers and students engage. Based on Vygotsky's (1978) beliefs that "higher order mental capabilities" develop first externally through socialization and modeling from adults or peers before they become internalized, Emihovich and Miller studied the social interaction between teacher and students in a Logo setting. Questions teachers asked were often of a metaprocessing type (eliciting questions, evaluative questions, and planning questions) which encouraged children to think about their actions and verbalize their thought processes. These externalized thought processes are gradually internalized as children engage in task oriented social interaction with adults or more knowledgeable peers as they learn Logo.

In the Logo microworld, the computer provides a mirror whereby the child sees the reflection of his thinking process. Through these reflections children can learn "to think about thinking and learn about learning and in doing so, enhance their powers as psychologists and epistemologists" (Papert, 1980, p.23). During debugging the child looks back on mistakes to determine the error in thinking and in doing so becomes familiar with his own personal style of learning. Once aware of one's style, it is possible to reflect on that style in a perturbational manner. Papert notes some resistance to debugging and suggests that this is a carry-over from traditional teaching methodology in which errors are considered "bad". Debugging encourages an acceptance of errors (perturbations) and by studying our mistakes we can come to understand the problem better.

Would not BASIC do as well? Papert (1980) says no, that programs in BASIC require a mathematical sophistication beyond the abilities of most students. BASIC established widespread use when microcomputers lacked the sophistication of today and is now an archaic phenomena, continuing to be the backbone of highschool computer programs even though other languages may be more appropriate.

Papert (1980) believes that Turtle geometry becomes a bridge to Polya and development of the problem solving abilities of children. Polya's (1957) four basic steps for problem solving are: (1) understanding the problem, (2) devising a plan, (3) carrying out the plan, and (4) checking the result. These provide a framework for both child and teacher in the search for solutions. The recursive nature of Logo encourages heuristic problem solving, where the child understands the whole picture through recursion to the parts often by using analogy or induction. Successful problem solving is an emotional experience beginning with a desire to solve the problem and requiring perseverance, patience, and concentration. Polya (1957) would criticize a traditional mathematics class where students have no interest in solving the problems assigned as this would deprive students "of the most vital point" which is the opportunity to become familiar "with the varying emotions of the struggle for the solution" (p.94).

Will computer technology be perturbational to the system of education? John Goodlad's (1983) extensive study of schools reveals that in most classrooms the teacher dominates and students sit passively. Gary Bitter (1986) feels that computers may have the power to encourage students to become active learners by forcing teachers to vary their methods of instruction.

> Ironically, the most attractive aspect of computers in education should be that there is simply not enough money in most schools to provide one for every student. Think about the implications for a moment - not enough money to give a computer to every student! This means that teachers who wish to use computers have a limited number of options. They can have students in small groups use the one or two computers housed in the classroom. They can use the computer in an activity center. They can use the computer for a whole class activity. Or they can reserve the computer lab, if one exists in their school, so that each child has a computer, if only for a day. These are but a few of the many options. But these, and many other similar options, require teachers who wish to use computers to restructure their classes (Bitter, 1986, p. 16).

The introduction of computer technology into my classroom had been perturbational to my teaching role. I wondered what students found so exciting about using computers. I wondered if other teachers were experiencing perturbations as they incorporated computers into their classrooms. The findings of the study presented in Chapter Five are the results of my attempts to reveal what was happening to students and teachers as they became involved with computer technology in the schools.

CHAPTER FIVE

FINDINGS OF THE STUDY

The study attempted to observe teachers and students in a variety of computing environments and have the teachers and students reflect on their interactions with one another and with the computer in those settings. Six computing environment were selected for the study based on information received during preliminary visits to the schools. Criteria for selecting the six computing environments in this study were: (1) the focus of the particular computing environment, (2) the number and location of the computers, and (3) the expertise of the teachers.

Through telephone contacts and informal visits to schools, it seemed that four computing applications; CAI, word processing, Logo and BASIC (also called Computer Literacy) were representative of what was happening in elementary schools at the time of the study. Environments selected were, at the time of the study, or had earlier in the year, engaged in one or more of these four applications.

Two schools had the computers in their classrooms, and four schools had a lab setting. The numbers of computers ranged from one in a class to seventeen in a lab setting. The ratio of computers to students ranged from 1:25 to 1:1.

The teachers of these classes had some expertise with computers, but due to the rapid changes in technology, the particular applications which I observed were often in their first year of operation.

In this chapter, six computing environments will be presented. Schools and computer applications are: (1) Hunter School - CAI drill and practice, CAI problem solving, and word processing; (2) Queens School - CAI drill and practice and BASIC; (3) J. P. Henley School - BASIC; (4) Riverview School - Logo, CAI problem solving, BASIC and word processing; (5) Eastside School - Logo and word processing; (6) Mayridge Heights School - Logo and word processing. Quotes from interviews with students and teachers aid the description of each environment. To facilitate fluency, extraneous words have been eliminated from quotes, however, care has been taken to ensure meaning was not altered. Comments have been added to the quotations to assist with meaning. These comments are enclosed in {} brackets. Interpretations within an orientation of dissipative structures and autopoiesis will be included in square [] brackets. Further interpretation will be presented in Chapter Six.

HUNTER SCHOOL: ANDREW

Andrew was a grade six student at Hunter School, a member of a class of forty-four students with core subjects being taught by teams made up of teachers, Mr. Watson and Mrs. Powell, and Assistant Principal, Mr. Cummings. Mr. Cummings was knowledgeable about computers while Mr. Watson and Mrs. Powell were relatively inexperienced. The computer lab, containing seven computers, was housed in a small room adjacent to the library and the class was allotted times in blocks of about one hour per day for one to three months. Andrew had participated in four different activities throughout the year: CAI for a social studies unit, CAI in mathematics using Milliken Math Sequences, word processing on Bank Street Writer, and a research project using Gertrude's Puzzles and Rocky's Boots.

CAI - SOCIAL STUDIES

Andrew showed me the social studies software which consisted of two parts. In the first part there was a menu from which the student selected areas in which questions would be asked (eg. climate, position in the world, mountains, lakes and rivers). The second part of the program was a test with questions generated in a random order.

> {Mr. Watson} We rotated all of the grade six students, in pairs, through during social studies period over a time of two to three weeks and when they felt they were ready they took the test. At the end of the unit they were given time to review. The program was designed so that they could call up any one of the sections on the menu and review some parts they weren't sure of. I thought it was very very motivational for the kids and it was a nice alternative to doing the geography just in the classroom, you know with atlases and books and so on. It was partially review but it also expanded and extended the concepts that we had studied in class. They seemed to have a fairly high retention of the facts. I think it brought out a competitive nature. The computers are all

> in the same small room so they were kind of able to keep track of where their neighbour was and what percent their neighbour had scored on each of the little quizzes. So they were a bit competitive and seemed very very motivated. Even the students that probably wouldn't, or in other types of activities in the classroom wouldn't, have been very interested in doing it. It seemed to aim for mastery. Almost all of them, unless they had 100%, wanted to redo the test, which is a bit unusual, although occasionally they will elect to do that on a classroom written test as well.

> {Mrs. Powell was less positive toward this activity.} I think it was all right for some of the students but I don't think it was the answer for everybody. I don't think there was that much learning that took place. {When students were} working with someone who was really sociable, they let that person take over. I am just thinking of the poor students that don't really do well in anything, Bank Street was better because they were on their own.

[To Mr. Watson good results (retention of facts) were achieved through a "bit" of competition. The observer cannot enter the cognitive domain of the child to determine whether striving for "mastery" is linked to acquiring the intended social studies content or whether it is linked to some other factor (i.e., student self-esteem). Skills and knowledge focused on in an autopoietic "mastery learning" environment would be perturbations in a recursive process bringing more meaning to and receiving meaning from skills and knowledge learned previously. In an allopoietic "mastery learning" environment the child would view the skills and knowledge as input to which he produces the correct response. If the child attains "mastery" in competition with others, to feel successful within the larger social system (classroom), the child has maintained his autopoiesis, but the learning activity has been allopoietic. Mrs. Powell spoke of "poor" students allowing stronger students to take over. The students coupled in this social system maintained their autopoiesis and supported the autopoiesis of the larger social systems of the classroom and educational system by relying on the "strengths" of one of the component members. Students produced results through cooperative rather than collaborative behavior.]

CAI IN MATHEMATICS

This grade six class used the computers for CAI in mathematics for two to three months between Christmas and Spring Break. There was one person per machine and they worked on Milliken Math Sequences, Addition and

Division. Students started at approximately level twenty on addition and when Andrew reached level forty he was assigned the division disk. I spoke to Mr. Watson about the assignment. He explained that different levels were not set for individual students.

> {Mr. Watson} We didn't do it that way because the levels that we set were fairly adequate for most or maybe all of the students. I can certainly see that being done. A lot of the practice programs available now have that capability and I think given the one on one situation that a computer gives, that it is certainly something that could be taken advantage of.

> {Andrew said he liked doing math on the computer} ...especially when the computer rewards. I feel really good when the computer rewards. They (students) try and work hard and get up to the higher levels.

> {Mrs. Powell questioned the value of this drill and practice activity.} I wonder about the Milliken because I have seen an awful lot of conversation going on in there and I think that they could probably be producing a lot more in twenty minute or fifteen minute period than they actually do. Like it's timeout from the classroom too.

[I feel it unlikely that Andrew, an enrichment student, would need to practice addition. As an observer, I feel, Andrew has participated in learning activities where his responses have been allopoietically controlled by directions of the teachers and by the structure of the software. The conversation, viewed negatively by Mrs. Powell, may indicate that students are complying reluctantly to the controls of the system by using it as a "time out" from the classroom.]

CAI - PROBLEM SOLVING

Andrew was also a member of an enrichment class which explored problem solving software, Gertrude's Puzzles and Rocky's Boots. I observed Andrew using Rocky's Boots. He worked through a sequence of exercises learning knowledge required for a final activity which allowed Andrew to build machines of his own. Andrew thought it unlikely that he would want to repeat the sequenced activities but the final open-ended activity appealed to him.

> {Andrew said he preferred to work on Rocky's Boots or Gertrude's Puzzles rather than CAI in social studies or math or word processing because it was} more like a game. You get to build your own machines, which is great, and after that Rocky comes up and rewards you.

> {Mrs. Powell} They really enjoy the open-ended activities, creating their own programs and systems on that. Everyone of them was really positive. They really couldn't wait to go back the next day and we did it every day for about six weeks for an hour. I think that if you are going to work on the computer, work consistently through a long period of time.

[Both Andrew and Mrs. Powell were positive toward Gertrude's Puzzles and Rocky's Boots. Within the scope of the software, Andrew was able to control his learning (autopoiesis). Recursive thinking was encouraged by the flexibility of the software. He could re-enter the sequenced activities at any step and the final activity of building his own machine was open-ended. In this computing environment the child and the computer software couple, independent from the teacher. The students in this enrichment class had access to the computers for an extended period of time. The success of this enrichment activity has been perturbational to Mrs. Powell. Through reflection ~~on other le~~ss positive experiences, she seems to feel an ingredient of a successful computing experience for students would be sufficient time at the computer.]

WORD PROCESSING

Students were instructed in keyboarding and word processing before being given an assignment to put on the word processor. The writing was begun in the classroom and then put on the word processor.

> {Andrew} I sometimes come in with it half written and then type that all out and then continue from there and then print it out on the printer and then correct the mistakes and x them out on the Bank Street Writer and then print it out again. I read through it once and try to see all the mistakes I can figure out and then I give it to the teacher. I prefer to start

writing it out with nothing at all. If you have to change a lot of it, you can easily change it with the computer.

{Mr. Watson} I think I found them being a bit more conscientious about their punctuation. When they could see how the word looked in print, I think it was easier for them to see that it was misspelled because it doesn't look like their own handwriting and they don't take it for granted. When you read your own work over you always see what you want to see rather than what's there. Maybe (in the future) we will be able to concentrate more on research and functional and creative writing rather than just getting things down legibly on paper. I think it may have resulted in a little bit better academic effort with one or two students. I would say that a certain amount of enthusiasm for writing was helped along by using the word processor.

{Mrs. Powell} We had a lot of practice typing the first two weeks. We really enjoyed that. I feel that there was more motivation in typing than the Bank Street. Students were able to prepare three things on Bank Street in the time allotted. Word processing takes seven away from your regular program and it wouldn't be the same seven. Some would finish in 10 minutes and some would take 30 minutes and it is difficult because we have a music switch and I was trying to carry on with language arts and of course the slow kids in language arts were also slow on the computer and it was very difficult to keep track of them and all their assignments. The teacher is away at the other end of the hall and there are seven kids down here and you can't be too quick, but our librarian aide is very good if they get sidetracked on not knowing what to do. Mind you the kids help themselves too.

[Writing, editing, and revising is a recursive process. Andrew finds the computer a helpful tool to facilitate the writing process. The reflections of Mr. Watson's recursive thought processes are revealed as he speculates about how computer technology may affect the writing process. Writing expert, Donald Graves, comments: "It is true we can publish without a computer, but the capacity for making multiple copies and the clean-looking print will make it more seductive for the student to keep going, to keep writing and publishing" (Green, 1984, p.21). Can word processing facilitate co-drifting between teacher and student?

To Mrs. Powell, however, the word processing activity is approaching a far-from-equilibrium situation. She is unhappy about the physical separation of the computers from the classroom and seems concerned about "keeping track" of her students. The music switch, too, complicates the movement of students. The feeling of responsibility Mrs. Powell has for supervision of students as well as scheduling problems within the school are constraining issues brought about by the larger social systems within which the computing environment is embedded. A word processing environment which nurtures an autopoietic writing experience for children depends for survival on its ability to promote third-order coupling between teacher and student. In Hunter School, the distance between teacher and student, during word processing activities, restricts coupling. Perhaps Mrs. Powell's support for keyboarding (CAI drill and practice in typing) was a response to her disillusionment of word processing in an inadequate setting. Mrs. Powell may choose to close her boundaries to word processing and return her language arts class to equilibrium.

In the absence of the teacher, students have coupled with one another. Perhaps, in time, students helping students in the computer room will become perturbational to Mrs. Powell as it was for me.]

GENERAL COMMENTS

Andrew commented about which computer application required the most thinking:

> {Andrew} If you start off easy with Rocky's Boots, it is about the same as Milliken Math. With Bank Street Writer you have to think of your own stories and stuff and it takes a little more thinking than Rocky's Boots. And the social studies unit is mostly if you have learned the other stuff that you reviewed before. So I think the Bank Street Writer would be the most because you have to think of things.

Mr. Watson was generally pleased that the computer usage in Hunter School was moving towards integration. Mr. Watson spoke about the changing role of the teacher.

> {Mr. Watson} It's definitely a different role. For me it's a role that I kind of enjoy as a change because you get to sort of be someone that the students consult rather than someone that is leading them through every little step of their learning process.

Mrs. Powell thought the students should be learning something about the computer, programming or learning Logo, so that they would be in control.

Mr. Cummings spoke generally about the program at Hunter school and about the future of computing in the schools.

> {Mr. Cummings} Well for my experience, I find computer activities to be one of the most cooperative areas that I have seen students work in. I don't notice competition, I notice cooperation. If somebody has a problem or something, somebody gets up and helps him.
>
> When we started out it was CAI and that is still okay but it is not the more important thing. Computer assisted instruction is falling further back all the time. It's an important use of computer but it is not as important as computer literacy, problem solving and word processing. We have to get away from teaching as though we were still in the industrial revolution and we have to say that we are in the information revolution. I think the information that we tend to disseminate has to decrease and we have to teach them how to acquire information. The student has access to the information that they need to do whatever it is they want to do, in consultation with teachers.
>
> My intention was to do some computer literacy - we never got around to that this year. I would like to get the school on some kind of network system so that the students can appreciate that kind of possibility. I will continue to look for good software and continue to encourage word processing. I am still fairly sensitive to doing things with students on the computer at the exclusion of some other students.
>
> I think it's unfortunate that we have several groups of people trying to deal with computers and how they fit into things and that's pretty frustrating. We have had three years of a lot of stuff happening in individual schools and I think it is time to kind of decide on a direction. It could come from the School Board or it could come from the Department of Education.

[For Andrew, the learning activities which best supported his autopoiesis were Rocky's Boots and word processing. It's interesting that he felt word processing required the most thinking. Perhaps this is because the process of writing is open-ended whereas Rocky's Boots is open-ended only within the structure of the software.

Mr. Cummings seemed to be uneasy about the inequity of computer usage in the school. (Only the enrichment students were using Gertrude's Puzzles and Rocky's Boots.) Although not addressed specifically by these teachers, one wonders if "low" students will spend a disproportionate amount of time doing

CAI drill and practice (allopoietic) activities while "high" students spend more time on open-ended (autopoietic) activities such as word processing or problem solving.

The feelings of teachers at Hunter School are mixed about the computing applications students participated in during this particular school year. Mr. Cummings desires more specific direction from School Board or provincial authorities. Perhaps good things can come from this lack of direction. As these teachers struggle with decisions about the use of computers in their school, ideas which support autopoietic learning situations are being discussed. For example, students controlling their own learning, teachers becoming consultants to students, and collaborabive learning among students. The experiences of the teachers may become perturbational and through coupling become cross-perturbational to other members of the teaching team.]

QUEENS SCHOOL: ANNE

Anne was a member of a grade six class at Queens School taught by Mr. Duncan. The lab was equipped with seventeen computers (Fifteen were of a type that had only small memory capacity.) and one printer. The computers were arranged in an open "U" shape. Two different computer applications were observed; (1) CAI - drill and practice during a "math centre" class and (2) programming in BASIC during a computer literacy class. The area in which the computers were housed had been used as a "math centre" for the previous four years. The computer application was in its first year.

MATH CENTRE - CAI DRILL AND PRACTICE

The students were arranged in groups: two groups sat at tables doing worksheets and two groups went directly to the computers. When the students with worksheets were finished and had corrected their work from a key, they were allowed to go to the computers to play math games or do Milliken Math.

Two students, at the computers with limited memory, caught my attention. One boy was typing in the answers before the questions came on the screen. All were correct and the computer just kept flashing but I could not make out the screen. The other boy was typing in any answer to see how high he could get the negative score at the end of the game.

> {Anne} The computers are fun all the time but the class can get boring. Like math, you're just sitting there trying to work out math problems. Here it's fun. You have challenges to work out the problems and in math you're just sitting there looking at math problems until you're bored with it. {The difference is} sometimes they give you a time limit. You don't know what to expect from it. It's kind of interesting and you get a little caption up at the top, "wow" or whatever and it's kind of neat.
>
> {Anne commented about making errors on Milliken Math.} Well it's kind of embarrassing because it takes its time. You get this big red x and

everyone is looking at you. {In class} you just mark it wrong and that's the end of that. It's most embarrassing because it stores it, right, and then I get it on my report card. {When it helps} it does it really slowly. I wish it would just hurry up and go on to the next question without everyone staring at the screen.

{Mr. Duncan} Initially they will line up to do drills and thoroughly enjoy it because it is a novel way of doing it. If they were to do math drills day in and day out the novelty would wear off very quickly because the computer doesn't know when to push the kid. It doesn't have consequences to it.

I don't think they should be used to get rid of discipline problems or those kids that could do with being closely monitored. I think often the kid that most need that completely individualized attention, the last thing he wants is a computer. It doesn't talk to him. He needs people. The last thing you want to do is to make him even more anti-social.

{Mr. Duncan didn't think the math drills encouraged competitiveness.} No more than peer pressure does. It may provoke a little self-competition particularly because of the time sequence.

{I asked Mr. Duncan about the two boys I had observed in math centre.} You are always going to get a kid that beats the system. As far as a computer is concerned, as long as it keeps getting them right or wrong, there is no consequence to it.

[In an autopoietic learning situation both correct responses and errors trigger perturbations within the cognitive domain of the learner. However, Anne would like to disassociate herself from error-making as error-making is incompatible with how she sees herself as a learner, or how she wants others to see her. The protection of her "public image", causes error-making to become embarrassing and she wishes the computer would "just hurry up". In the classroom she quietly separates herself from errors by marking them wrong and forgetting about them. In this allopoietic learning environment, the child conducts a divorce within herself, separating the mathematics which could be learned from her cognitive development.

The boys who were as Mr. Duncan described "beating the system", were able to maintain their autopoiesis within the controlling influence of a larger social system. The activity may have been viewed as too hard, too easy, or uninteresting, but whatever the reason, these boys closed their boundaries and escaped. Autopoiesis cannot be denied.

Mr. Duncan does not believe that computers will be the answer for students with learning problems as they may make students more "anti-social". His comments suggest a belief that these students need to engage in third-order coupling with others who can support their autopoiesis.]

COMPUTER LITERACY - PROGRAMMING IN BASIC

At the beginning of the computer literacy class, Mr Duncan, stood in the "U" and passed out disks. When everyone was ready, he turned on a power bar that controlled all the computers. The students were programming, in BASIC, two assignments which required them to apply content learned throughout the year. The first assignment was to have the computer accept an input (user's age) and then output the age that person would be in the year 2000. The second assignment was to create a menu for an imaginary restaurant (McDuncan's Computerized Restaurant) which would allow a user to input any number of hamburgers, fries, and drinks and the program would output the total cost. If they were able to solve the problem as described above, they were to add their own enhancements to it. A mathematical equation was required to manipulate the input and the colorful graphics background was created by using symbols on the keyboard. The assignment was to be marked by Mr. Duncan with ten marks for solving the problem and five additional marks for extras added to the program.

Students were seated two to a computer and there seemed to be an excitement in the room as they worked on their programs. As difficulties arose, the students would raise their hands and Mr. Duncan would come to them, look at what they had done, and offer suggestions. Although there was considerable discussion between partners, there was very little discussion from one pair of students to the next. I observed during the class that Anne and her partner, Sara, put their binders between their computer and the one next to them on either side.

> {Anne showed me her program.} It was fun. Me and Sara did it. She's my partner. It's not bad.
>
> {She liked working with Sara.} Well say I get mixed up while I'm working, she can figure out what I did wrong or she can do the typing and I'd read. It's faster. When I'm away, she can work on the program.
>
> {I asked about the binders between the computers.} It's kind of a race. We want to get Mr. Duncan over here. We did it first type of thing. It's a challenge.
>
> {Anne commented about mistakes made when programming.} I got these numbers mixed up and when I ran it later it wouldn't work. The program was only half done, but it was a really nice program and it really got me angry at it. I started over and I did it.
>
> {Anne thought she would get a good mark on her computer assignment.} I get a six out of ten in class. Like they're okay. I don't usually worry. I get six to nine. I don't usually get perfect but I don't usually worry about it, but I like my computer mark a lot. I don't like anything low because I could do better on it. I don't know. I find it easier.

> {Mr. Duncan} Computers provide a mental challenge that can be used after the initial instructions that the teacher gives them in teaching BASIC. It's a problem solving device. It teaches the kids to think logically and they (computers) are pretty stern task masters. There is no room for mistakes. It is either right or wrong.
>
> {Students created "extras" for their programs using the preprogrammed graphics on the keyboard of the computers used in this setting. Mr. Duncan commented about this.} There are so many right answers. A kid can change the colour screen by using the code command and he can change it by using the reverse and a space bar. One is not better. One is more simple, uses less memory.
>
> You (the teacher) are still really doing the same things you would do in the classroom. The difference is in the initial stages of computer literacy it is all teacher output. It is exhausting because it is continual ouput until they get used to the idea of seeing what they can do and starting to

think. As they become more and more competent, then your role changes to one of an aide.

{Mr. Duncan thought the reference to marks was a spin-off from the classroom.} Funny because I haven't marked them and not one of them have asked me to. I push that as a class. Marks are very important. Whether they like it or not, they are important. They like to feel there is some sort of evaluation because they, themselves, put a value on it. They need to know that their work is going to be judged because if they don't it makes it meaningless. They like to see a mark because they use it as their own yardstick.

{Mr. Duncan has difficulty evaluating problem solving.} That's why I haven't marked it. They are getting the satisfaction of working on the assignment and they have worked on that for ages. There is a self-satisfaction. You can tell that because they are dying to show me their progress.

Grading is something we have to get away from but I don't know how because in everything, somebody hangs a percentage on it. There are a couple of girls that are not logical at all. One of them is just finished the program today but you should have seen the smile on her face. She's six weeks behind everybody else but she solved something. You want them to perceive the course as meaningful throughout, but there are kids that will not do anything without somebody saying, "Okay, I'm going to evaluate." Because of their background environment there is no expectancy to achieve and so they don't.

[Control is moving from teacher to student. The teacher specifically determines the mathematical components of the programming assignment, but the students control the graphics component. In contrast to the CAI activity where Anne boundaried errors, Anne in this environment, embraces the errors. She becomes "angry" with errors but persistently works toward a solution.

Mr.Duncan recognizes the "self-satisfaction" his students have toward problem-solving in BASIC, but he holds firm to formal evaluation as a tool to motivate his students. The experiences we had as students and those we have had as teachers within the larger educational system which mandates the use of grades contributes to the structure of our system of perceptions. Perhaps the observations Mr. Duncan has made of his students who were "dying" to show him their programs will become perturbational to his system of perceptions. The competition between partners for teacher attention may be residue left from the classroom in which marks are emphasized.]

J. P. HENLEY SCHOOL: RYAN

Ryan was a grade five student at J. P. Henley School. Students in this class participated in a computer literacy course which included instruction in BASIC programming. Five computers on rolling tables were positioned at the back of the classroom along the wall. The teacher, Mr. Moore, introduced a problem and then five students at a time went to the computers for about one-half hour. The rest of the class was working on non-computer activities which could be done fairly independently. During the class, Mr. Moore spent most of the time at his desk working with individual students. He explained that he purposely planned seat work activities when the computers were in the room so that he was available for both groups. He also felt that a maximum of seven computers could be handled in this particular setting.

The focus at the time of the observation was problem solving and students were attempting to create "string designs" using high resolution graphics. When Mr. Moore visited the computer area, he helped students by telling them, "I'll give you a little clue," and then letting them try to reach the solution alone. I observed among these students a determination to solve the "string design" problem. Generally they programmed each line of the string design separately and when a pattern emerged, they would delete the lines and write a new, shorter, program using FOR/NEXT loops. Once the problem was solved the rest of the time could be spent experimenting.

> {Ryan} We have been doing a bit of literacy work, like typing these programs that the teacher gives you, like see what it does and then you write down the output. Then, later on in the year, we went into color graphics.
>
> Five kids get a half hour and like you try to do as much as you can in that half hour. If we have periods for a whole day we could get about two turns in a day for a week.

You can do lots of things. Like you can make nice patterns on the screen. Making designs is easier to do on a piece of paper but when you are doing it on a computer, you have to type in all these statements and sometimes it doesn't work and that's the challenge about it. {When it's finished} I want to run and show it to all my friends. When someone gets a program, and it is really neat and everybody likes it so everybody is wanting to see it, 'Hey look at what I did!' and it disturbs the whole class. {Sometimes students} bug you and say they can do a better program than that junk. Some programs are pretty good, but I have had some programs that aren't that good but I don't admit that it is not good.

Before, earlier in the year we had to make the computer count to a certain number and then stop and I had trouble with that. It didn't bother me that much though. {It would bother him more to be unsuccessful in his other subjects} because you don't want to fail a grade in school and you have to try to do your best. The computer is extra, but we still have to learn about the computer too. If we want a good job when we grow up then we have to know a bit about computers because the economy has all gone to computers.

{Mr. Moore} I've tried to work through all the five questions put through by Alberta Education; what a computer is, the use of a computer, etc. In the early part of the year, for example, since I am working with BASIC, we looked at learning a number of BASIC statements. It takes quite a while to get to the point of being able to solve problems with a computer. I try to keep a discovery approach even in the early stages of learning about the machine and about BASIC.

{When they were working on the mathematics problems} there were some kids that had difficulty although I think the problems they were attempting were difficult. They often had to recognize a number pattern, let's say a square number pattern or a triangle number pattern, and then write a program. I felt it was a fairly high level type of problem solving for kids. But surprisingly, a number of them still got it, but I felt more might have got it if I had changed the order.

{Mr. Moore felt the "string art" was easier because of the} visual effect of what is happening. Whereas the number problems remained as an abstract idea. {With the "string art"} they had something visual to connect to right away and as a result, they got information much more quickly as to whether they were on the right track or not. So there are little clues for them along the way that help them stay longer, to persist, to get the final solution. Whereas in their other problem solving work, they may only realize that they are finally at the solution when they get it. I am more apt to help them all the way at certain points, but since the focus was on problem solving here, I try to give them that one more step that might make them reach the final product by themselves and I leave them alone.

When a student is at his desk and runs into a problem, for example in math, he has to wait until the teacher has time to get to him. When children are interested in something and have to wait too long for help, they lose interest. They can make errors at the computer and don't get embarrassed because there is nobody personal there looking over them or laughing at them. They are free to make mistakes without feeling humiliated.

{Mr. Moore commented about a boy I had observed struggling with the "string design" problem.} I remember him sitting there and not asking anything and he did not have too much accomplished, but I kept an eye on him and it wasn't the next period, it was two computer turns later that he finally put everything together and then he came to show me. He had the problem beaten and was he happy.

{No specific computer literacy mark was given.} Students get the feeling of doing well from information as they are writing the programs rather than me coming and saying in my evaluation that they deserve this mark.

[At the time of observation, this computer literacy classroom, for the most part, was an autopoietic social system. Mr. Moore and his students coupled intermittently as Mr. Moore offered "clues" to help the students solve the problems themselves. The structure of the autopoietic learning situation depends upon the exchanges between teacher and student. The computer can at times substitute when the teacher is not available for coupling.

Mr. Moore said that it took "quite a while" to be able to solve problems in BASIC. Extensive access to computers (sometimes an hour a day) facilitated students in this class going beyond learning BASIC statements to solving problems.

Mr. Moore's observations of his students solving graphics and non-graphics problems were perturbational with recursive thinking resulting in a decision that a structural change (doing graphics before the mathematics problems) in the computer literacy system would help facilitate the autopoiesis of his students. Mr. Moore supported student independence and the immediate graphic response to an error became perturbational to the student, encouraging student control and persistence. Ryan, and the other boy in the class who I spoke to Mr. Moore about, experienced pleasure as they were able to solve the problem. Although Ryan recursed on the nature of his programs that were "not that good", he refused to display the results of his recursion to his classmates but instead protected his public image.

Mr. Moore's decision not to formally evaluate problem solving seems based on his value of the recursive process within the child that is not revealed through observations (reflections) of the problem solving behavior. Ryan separated his computing experiences from the regular school work. Perhaps this was because it did not appear as a separate subject on his report card.]

RIVERVIEW SCHOOL: BRENT AND SCOTT

Brent and Scott were students at Riverview School where there was a computer in each of the division II classrooms and one available in the division I wing of the school. In Brent's grade six class, the computer sat at the back of the room and was equipped with a modem, printer, and graphics tablet. On the wall behind the computer a chart showed the times when each of the students could go to the computer. Early in the morning, three or four kindergarten children identified as "bright" came to this class for enrichment. The computer ran from morning to night. Students generally worked alone. If something was difficult or if someone was trying something new, another student could serve as a tutor.

Mr. Locke, the grade six teacher, believed the computer should be in the classroom and strongly opposed uprooting kids and taking them to another room. He said the one computer in his classroom was their (students) computer. He would prefer to have more computers in his classroom.

The computer program consisted of computer literacy (main frames, and mini and microcomputers, ROM, RAM, chips), low resolution graphics, word processing, high resolution graphics, telecommunications, and Logo.

BRENT

Mr. Locke introduced me to Brent who was attempting to produce a picture of a Macintosh computer using Logo. I observed Brent on two occasions about ten days apart. On the first occasion, Brent was writing the procedure for creating the Macintosh design as one long sentence. On the second occasion, he was using miniprocedures and adding them to a superprocedure but was still not using the same procedure more than once.

Between my first and second visits, Mr. Sullivan, a friend of Mr. Locke had given Brent some pointers on Logo. Mr. Locke's expertise lies with BASIC.

> {Brent - I asked why he liked working on Logo.} It makes me feel pretty good that I know how to do it. It makes you feel better that nobody hardly knows about it but you. It makes you really think. {Mistakes while doing Logo don't bother him.} No, you just have to think a little harder how to do it. Well Logo is just for fun but math is for work and makes you kind of get upset when you don't get too good in math. I would feel kind of upset because you need a good education to pass through school and go to college.
>
> {Brent commented about word processing.} It's good for typing out letters and different things. You can see if you're doing a paragraph and it isn't right you can learn to fix it. {Brent referred to Bank Street as "reading" and felt that it required the most thinking,} because you have to read it, proof read it, and think it over.
>
> {Low resolution graphics} I like it because you can do Pacman, Frogger. Graphics is like Logo except Logo has skinnier lines. Graphics has little squares so it comes out like little square Pacman. {Brent didn't think graphic required much thinking.} All you have to do is put PLOT whatever it is on the screen. You have a little graphics paper. It has 1 to 30 here, 1 to 30 there. The you just figure out where it could be. 5 to 1, or something like that, and you make a dot there and keep on going.
>
> Like computers can teach you lots and when you go to Jr. High they have all computers and you can learn quicker computers.
>
> {Mr. Locke} Brent is a below average kid and he got into this thing. I brought out the Macintosh and I said to him, "Here do that in Logo." We allowed him how to do all the different procedures and he caught onto that and he developed his own little routines for moving and everything. He was really excited about that. He worked for a good month.

[Brent, a below average kid, became intrigued by Logo possibly because he found it to be non-competitive and non-threatening. "Low" students have difficulty maintaining their personal worth within the larger social system which praises academic achievement. Brent's Logo experiences have been perturbationally supportive of his internal structure because he feels he knows something the others do not. Intermittent coupling with his teacher and Mr. Sullivan support Brent as an autopoietic learner.

Brent speaks of Logo being "just for fun" and math as being "for work". In an autopoietic learning system, both pleasure (fun) and work recursively nurture the system.]

SCOTT

I briefly observed Scott playing a game called Thinking with Ink, a program on Problem Solving Strategies from MECC, and later discussed with him other computing experiences he had during the year.

> {Scott said the object of Thinking with Ink was to} color the maps for the cheapest price and that's a lot of fun and you have the top ten and it's fun because there's big maps and different colors to color the map with. It's sort of a challenge to do it the cheapest. When you're finished, you feel good because you did something that no one else has done. {Would he be interested in doing Thinking with Ink again?} Ya, I'd try to get all the top scores or the first and the second.
>
> {Scott commented about word processing.} It is easy to use and if you make a mistake it shows you how to get out of it. If you put in words you don't want to use you can go to the erase menu. You can learn how to write things easier and correct them easier. It's neater and if you want to change something you can just go to the program and make the corrections and print it out again.
>
> {CAI in math} The math wasn't very hard but the challenge was to get the correct answer before they get you.
>
> {Graphics} I felt good because I thought it looked neat and my program was reaching just about two thousand, going by fives. It's fairly easy to correct the mistakes. It's more fun to correct at the computer.
>
> {Scott compared using the computer at home and at school.} At school you learn more than you would at home. At school you're being taught to use it and at home you probably would be working out of a book or what you discover on your own.

> {Mr. Locke} What I do every year is start with a very BASIC computer literacy, just to kind of brush up the kids that have really never had any

> exposure to computers at all. Then we go into low resolution graphics just to give the kids a little line number programming expertise, being able to SAVE, etc. Then we go into the Bank Street Writer, not the Bank Street Writer anymore, we use Writing Workshop by Milliken and we have them do reports on the computer, research reports. They do their outline on the computer, do their report on the computer and the enthusiasm from writing their first report was much greater when they did it on the computer. Then we go into high resolution graphics, PLOT, very simple things like that but just to give them an idea of the difference between the two graphics. We have done telecommunications. The kids are familiar with logging out the Source, getting information from Associated Press. It gives them the idea that a computer is used for more than sitting down and doing local things like drill and practice and word processing, etc. They have a link with the outside world now. It gives them a whole new idea about computers that they didn't have before and I think that is important in grade six too. It's a general exposure to computers and I don't put any pressure on them at all. I have that one display up that has low resolution graphics, Logo, and BASIC sheets and if they choose to do whatever they want then it is fine with me, but everyone of them are up to a good working level of BASIC. They are not advanced by any means but they have got the first five or six steps. To end off the year, I brought out my games for the first time. So they have been playing games for the last two weeks because they have done a super job on the computer all year and they are familiar with the computer and I think it is going to be noticeable when they go to Jr. High from this school.
>
> The low resolution graphics is marked and they are given an exam after the computer literacy. The report written on the word processor is marked only for content. They know the inside and the outside (of the computer). They have a good general exposure to microcomputers.

[Thinking with Ink is CAI problem solving software which encourages recursive thinking for some students who wish to see, or feel they are able to get, their "names up in lights".

Scott feels positive about learning more at school because he gets taught at school. Scott learns, not from being taught, but from information becoming perturbational to his cognitive domain. At school many opportunities for coupling exist with students and with the teacher. The social nature of a school encourages coupling which may be perturbational to the components of the system.

Mr. Locke has incorporated computer technology within his class keeping the system in a near-equilibrium state. He recognizes the role of the elementary classroom within the larger educational system and prepares his students with a "good general exposure" to be successful in Junior High. The activities he has chosen for his students are ones in which the students of this age can be successful. Mr. Locke encouraged the students to be in control of technology by speaking about the computer as their computer, by using the computer to get up to the minute information from the Source and Associated Press, by making them aware of many different computer applications, and by providing the opportunity for them to choose what area they wished to pursue.]

EASTSIDE SCHOOL: BRYAN, CORY, AND SUE

Bryan, Cory and Sue were members of an enrichment class of five grade six students at Eastside School that met for one hour each week for a period of three months. Earlier in the year an enrichment activity for grade six had focused on word processing with Bank Street Writer. Some of the same students attended both sessions. Enrichment classes were held in a small room adjoining the office with a machine for each student. Mrs. Preston was the enrichment teacher.

The focus of the class was problem solving. Students were presented with problems which they solved and then developed Logo designs to represent the solution graphically. Problems were of the type: What are the total number of squares on a checkerboard that is 8 X 8?; What are the total number of bricks in a pyramid with a base of "n"?; If a farmer had 14 animals and the number of legs were 44, how many pigs and chickens would there be? They also developed Logo procedures for tangram pieces which were later arranged to form tangram pictures such as a bear, a whale or a man.

Mrs. Preston designed the class in response to the desires of the children. On a questionnaire students indicated that they did not want to share a machine but that they did want to work on the same problem. Logo was new to these students and primitives were introduced by Mrs. Preston informally as needed. The only formal instruction occurred when students were taught how to use the editing features of Logo.

On the day of my visit each student was busily attempting to create a picture that was composed of shapes of a tangram. They each had a set of tangram pieces that they could manipulated into the desired shape and on these tangram pieces they had written the dimensions of the shape. As they worked Mrs. Preston circulated among them providing assistance where necessary or where requested.

BRYAN

{Bryan enjoyed the freedom within the computing environment.} Well, Mrs. Preston lets us do whatever we want and sometimes when we make a mistake it looks really funny. Sometimes it can be really fun for kids and they might work harder doing that and it really helps educate them better.

{Bryan preferred working "solo" in the classroom but in the computer room he said,} Well with the computer it is actually a totally opposite case. I like working with other people. I just prefer to work with somebody else on the computer in case I find something that I don't know. They might know it and we can help each other.

{Bryan spoke about what kids can learn in different computer settings.} Well in BASIC, they can learn almost anything, like spelling, math, and graphics - whatever the person programmed the program to do. Word processing's sort of like L.A. - like you are editing and making stories and making poems. Logo is mostly design and thinking a lot. It keeps your mind working.

{Mrs. Preston} Bryan is a very meek boy. He is a very bright boy and school is not difficult for him but coping sometimes is difficult and so he runs into frustrations. This has probably been his best year in school. He seems to really have gotten hold of his moodiness. He used to be mean to the little kids and he has been much better. He has gotten a lot of things worked out. He has a good rapport with his homeroom teacher and he and I have made out really really well but I know it hasn't carried through in some of the other areas.

{Mrs. Preston told me of the day Bryan digressed from the group assigned problem and decided it was necessary to fill a square.} It was totally off topic that day but was a delightful side trip for us and we all then spent a whole hour working on what he had discovered and, of course, that made him feel just super super good. His discovery was really truly neat. It was something that I would never have taught them this year. I would never have approached it because it wasn't in the area that I was looking.

{Mrs. Preston described another occasion when Bryan struck out on his own. The group was working on the problem of the chickens and the pigs. Squares and triangles were being used by the other students to represent the animals but Bryan insisted that his chickens and pigs looked like chickens and pigs.} He has this silly little thing that really truly looks like a chicken and he spent probably a whole hour making that chicken so that he could then use it in the problem. The rest of the kids would have said 'Make a square or make a triangle, that's it.' The triangle can stand for the chicken and the square could stand for the pigs, but Bryan had to fuss over it and he was, in that way, able to do his own thing and I think he has found that really satisfying with the computer. He can go off on his tangents and do something that others appreciate.

{Mrs. Preston commented about word processing.} When they start out, the kids in word processing are probably every bit as keen. They have something new to learn and they are enthusiastic. But when I got to the end of my four months, they were willing to quit.

[Bryan seemed perturbed by the lack of precision in the graphic representations accepted by the other students. Perhaps the support he received from the teacher and his peers when he digressed to fill the square served as a catalyst to move him further away from equilibrium encouraging him to attempt to produce a chicken that looked like a chicken.

Perhaps students are less enamoured with word processing because they view it as more language arts. Would enthusiasm remain high if word processing was part of the ongoing structure of the writing process within the classroom?

One wonders if the computer atmosphere where Bryan can go off on his "tangents" (has control) has contributed to the improvement in his aggressive behavior.]

CORY

{Cory also enjoyed the computer enrichment class.} You get away from the crowded classroom atmosphere and have more of a fun time. In the classroom it's mostly discussing going on and in the computer room you don't have to discuss unless you have a problem. In the classroom we start each morning, we review everything. It's okay, but sometimes you get too used to it and it gets boring. It's as much fun in the classroom when we are working on things. When I solve a hard problem, I feel pretty good because I can keep on going.

{Mrs. Preston commented about Cory's behavior in the tangram project.} He is willing to give the others, sort of a little bit grudgingly, I guess, but he is willing to give the others his things. He doesn't want anyone else's. If you loaded it on his disk, he wouldn't use it. Didn't even want to bother loading it, whereas the others were willing to share their things and still it would be their picture as they are putting it together. It is not that he is going to let his assignment be less effective in the end because he programmed four different shapes. Nobody else had four. He took those shapes and has done two pictures with them which is more than anyone else has. So you know he is a worker. "Why bother with someone else's things. I have got enough of my own to complete the assignment."

[Autonomy and hard work are structural components of Cory's organization as a living system. Although he was encouraged to share with others in a collaborative type of learning experience, he chose not to participate. The social system, by accepting his personal learning style, has supported his autopoiesis.]

SUE

{Sue commented about her Logo experiences.} I started off on my own and then my friend was having problems so we started to work together. It kept getting frustrating because it never worked but you thought that it should but it didn't. I didn't really want to give up because I knew we had it before so we just had to find out what we did with it. Mrs. Preston tries to make you solve it yourself and if there is a real problem she'll help. {Sue felt "relief" when the problem was solved.} We were glad that we could actually figure it out. We had an open house and we showed it to all the people there because we were kinda proud of it.

{Sue commented about BASIC and Logo.} The Logo commands are rather easy. There is about 10 of them at most and then for BASIC there is just so many you have to keep a book and look them up.

{Mrs. Preston} The girls share back and forth so freely. I think they share back and forth with most things, like houses and sleepovers and the whole bit.

Sue was stuck so I said, 'Fine, I will give you some help.' because I realized the problem was hard. So I sat down and worked on a method with her. I came back 15 minutes later and she wasn't even touching what I had given her. What I had talked to her about, I guess, had just popped another idea for her and she decided she had to try her method and see whether it would work. She never touched what I gave her and it wasn't that she didn't understand what I told her either. You know, she wanted to apply something else in her own way.

{Mrs. Preston also spoke of the difference between BASIC and Logo.} They are determined to go their own direction with Logo. Things that really appeal to the Logo kids is that they can adapt things and still make something out of this whole thing and lots of times their mistakes are really fantastic learning and are more exciting than the original project was. They can get really neat things by the goofs in their work. I found that Logo is different than BASIC because the problem can only be solved in one or two very similar ways with Basic. It can't be solved in this multitude of ways. If I were still doing the computer literacy program here, I would still teach BASIC because I think that BASIC meets different needs for the children. There are some of the kids that like the rigidity of just going through it. Logo is much more open, much less structured, to me than BASIC. When people say to me, 'What are you going to be doing in three weeks?'. I can't tell them because the kids influence what I do with them much more than they did when I taught BASIC. When I taught BASIC I knew what was coming next. You know it was all set out, and still is, in my mind. Just the method that I would use, not that everybody uses the same one, but for me I had a structure there. In Logo I thought I had a plan, but it keeps getting changed. So that is probably one of the big things, that I have become more flexible in what I do with the students.

[This Logo computing environment supports the autopoiesis of the students. The social system of the enrichment class was a creation of adult members of the larger social system of Eastside School in response to perceived needs of these students. By designing the structure of the class around input from students, Mrs. Preston has encouraged a feeling among students that the enrichment class emerged spontaneously. Once established the autopoiesis of the component members (teacher and students) supports and maintains the autopoiesis of the social system (enrichment class) and the autopoiesis of the enrichment class supports and maintains the autopoiesis of the component members.

Component members engage in third-order coupling with perturbations of one component member becoming perturbational to other members in the system. Observations within the computer environment moved Mrs. Preston into a state far-from-equilibrium. Bryan's insistence to "go his own direction" was cross-perturbational to Mrs. Preston causing her to recurse on past experiences and teaching methods within a BASIC computing environment. She described her reflection in terms of a behavioral or role change of being "more flexible" in the Logo environment.

As students and teacher couple in this environment, a true collaborative relationship emerges. Sue did not feel compelled to follow the advice offered by Mrs. Preston. The software (Logo) serves as a catalyst encouraging a far-from-equilibrium state among component members and errors become perturbations encouraging further learning.]

MAYRIDGE HEIGHTS SCHOOL: ELIZABETH AND AMANDA

Elizabeth and Amanda were grade six students at Mayridge Heights School. Mayridge Heights had eight computers, each with a color monitor, and two printers. The room was pleasantly arranged in an alcove off the library and adjacent to the grade six classroom of, Mr. Murphy. Mr. Murphy was temporarily replacing Mr. Sullivan, who normally headed up the computer program in this school. Mr. Sullivan was on leave but did visit now and again. His emphasis was on Logo and word processing. The class was broken into groups that were scheduled into the computer lab for one-half hour classes each week. Some students were allowed to go to the computer room when their work in the classroom was finished. Mr. Murphy felt that because the children had two years of Logo they were getting bored with it. As Mr. Sullivan was not in the school on a regular basis, students had to tutor each other and Mr. Murphy felt this had a negative affect on their attitude. He felt that many of them would like to learn BASIC as they could use it on their home computers.

The usage of the computers at Mayridge Heights has changed over time. Initially the major focus had been CAI and computer literacy using BASIC. Later the emphasis became Logo and word processing.

On the day of my visit, Elizabeth and Amanda were working together preparing a picture of a house with window, door, attached garage, tree and driveway, that they would be showing at the computer fair. When I suggested a curved path, they rejected the idea saying that it would be "too hard". They also began to put a sun in the sky and when they experienced difficulty with the spokes about the sun, they changed their minds and made a moon and some stars and were planning on adding color to the windows to represent light. At one point, the teacher, Mr. Murphy came over and suggested a chimney. The girls said they didn't want one.

> {Elizabeth and Amanda described Logo.} Logo is a way to learn to try more and not to give up. Like if we couldn't get this, we shouldn't give up because we would get it, like we got it now.
>
> How do they cope with difficulties in the classroom?} If the teacher's there we go and ask him. The computer's just like a machine and you gotta experiment. So we tried about twenty ways to do that and we got it after that because we didn't give up.
>
> {In the computer room,} we share the things and we work together and it goes faster too. Mr. Murphy, I think he trusts us to work together instead of fooling around. Sometimes when the kids get together they don't work, they just talk about what they are going to do and things like that, but they are not doing anything. So sometimes they're not allowed to work together. When everybody's working in the classroom, you have to work too and then you're also afraid that you won't finish before... and you try to work harder but here, in the computer room, I can relax and try to work. There's more time and I don't try to complete to finish before everybody.
>
> {Mr. Sullivan} Amanda and Elizabeth have accepted a kind of notion of community of learners. They have realized that there are certain kids who have lots to offer and that they associate and work well with those kids. They are very self-disciplined individuals. They don't rush ahead doing their own thing. One of my first objectives is that kids work with other kids on a problem, knowing that some kids never tend to work well with other kids. Let's say a group of four may splinter off into two groups of two or a groups of two may realize that it has irreconcilable differences in the way they are thinking about a problem and they go their separate ways. That's okay. I like to start projects with either two or four knowing that groups don't always have to stay together. Plus it's one good way to use a limited number of computers in a large class.
>
> I really think the computer, although it can be used very well to control what kids learn, can also be used as a tool for the kids to be in control of their own learning and I see Logo as a language that is more suitable for that philosophy. What I would like to see more, when I see students working with Logo, is that they somehow initiate their own problems and their own solutions to the problems and that's the direction that I am trying to proceed. To a certain extent, it has been successful with some kids. I don't know how many kids, but a lot of kids kind of feel that feeling, "Aha. I can do these things on my own." It takes a little longer

than what I would like to see but some kids do realize after a while that they can find their own, develop their own problems, and work on their own solutions and they feel really good about it. So that's the direction I am taking.

The keenest people in my room were the two best and the two lowest students. One low student really liked to work with the computer because he felt he was doing something worthwhile, different and interesting and he didn't get any negative feedback and so he thought he really liked computers. All his experience in school was based upon his inability to do things. At least with the computer it didn't make any big deal out of it. He didn't get bad comments or anything. So maybe it's a good environment for some kids. At least it makes them feel somewhat at ease with themselves as far as being able to learn.

And, of course, the bright kids really get off on the computer because they realize after awhile that they are in control. And most of them are so intelligent, when they realize that they just get all fired up and make the computers do anything they want. There are kids, like James. To him the computer is just an extension of his, I think, of his mind. Like he doesn't look at it as a detached thing. He just uses it as a real intimate tool that he can use to do all sort of things.

I kind of see word processors and Logo as being very similar. I see them both as microworlds. The Logo microworld is definitely more powerful. You can explore more concepts. You can do graphics and text and you can play around with ideas. Then again, you come to the word processor which has the same attributes. You can play around with ideas, you can put together ideas, you can combine. So you can use word processors for composing stories or letters. Some people spend a lot of time teaching word processing skills. I don't really go for that. I think, like Logo, let the kids learn by solving problems. I think both are the same. Word processing is a language itself. That's not really true in the technical sense, but it's an environment that you can play around with ideas, whereas Logo is the same kind of environment, perhaps more powerful.

I have used Milliken Math a couple of times this year for some students that didn't have a very good understanding of some of the basic math concepts or skills. One girl found it interesting. For some reason she like the idea of being plugged into a machine for twenty minutes and x number of division questions, getting some reinforcement or feedback from the computer. She liked that and some kids do like that and I wouldn't say that there is no value in using Milliken Math. I think it has some value in drill and drill is so important for some kids to learn.

I think you could use BASIC, if BASIC is to be taught, where you just have short little programs that solve basic mathematical type problems.

> I can see some value in teaching BASIC that way. I think the proceduralness of Logo or the modality of Logo tends to encourage people to make small stabs at solving problems. It breaks into parts, where you really can't do that with BASIC. Breaking problems into parts is a way of thinking which we haven't really encouraged in our school system. We tend to want students to solve problems completely. I think you have to give them project ideas that lend themselves to breaking a problem into smaller problems. I think that is where our role is, giving them project ideas because we have been exposed to quite a variety of books and references. I think maybe one of our jobs is to kind of spring these ideas on the kids because a lot of the kids are really not in the business of thinking up ideas. I think by choosing certain kinds of ideas, it helps them develop the idea of modular thinking or procedural thinking.
>
> I think my work in computers has helped my understanding in mathematics. Before I really didn't like mathematics at all. Not that I really show it now, but I appreciate it now, where before I didn't appreciate it too much. I think my computer involvement has given me the opportunity to think more about what education is and what education might be in the future. Whereas I was kind of going from a day to day teaching experience, now I think I am at least trying to understand in more general terms what my role, what a teacher's role is, in the education system. I think you have to develop some technical expertise to understand what computers are all about, but I still think that the most important thing is not to embrace the machine but to embrace the learner, so you don't lose perspective of what our role is all about, teaching kids.

[Elizabeth and Amanda are collaboratively working toward a mutually satisfactory solution to the house design. Logo provides the boundary constraints, but they control the problem, the process, and the solution. As they experiment with their ideas, reflections of their thinking, in the form of graphic images, serve as perturbations, encouraging further experimentation. The "relaxed" feeling the girls have in the autopoietic computing environment is contrasted with the pressure they feel within the classroom. This pressure is an indication of an allopoietic system which encourages achievement through competition among its component members. The larger educational social, system which emphasizes student achievement, also places stress on "low" students. "Low" students, however, can be autopoietic learners in a Logo environment.

Student autonomy is encouraged in the computing environment. Mr. Sullivan feels his role is to initiate problems for groups of students until they are ready to initiate their own. As these problems become perturbational to students, the original grouping moves far-from-equilibrium and, at a bifurcation point, when the thinking processes of their cognitive domains are "irreconcilable", new spontaneous social systems emerge. The teacher remains as a component of each new social system. Survival of these systems depends upon coupling between the members of the new system. Mr. Sullivan's extended absences from these systems has contributed to the breakdown of some of the systems. This is supported by Mr. Murphy's observation that some students were losing interest in Logo and wanting to learn BASIC.

Computer technology caused the "day to day teaching experience" of Mr. Sullivan to move to a state far-from-equilibrium. Perturbed by the technology, Mr. Sullivan reflected on coupling experiences with students and fellow teachers as he attempted to "understand what computers are all about." Perturbations as he maintained his autopoiesis within the social system of his classroom resulted in "trying to understand in more general terms (his) role, ... a teacher's role, in the education system." Perhaps computer technology will be perturbational to others, as it was to Mr. Sullivan, encouraging teachers to reflect on their "day to day" teaching.]

CHAPTER SIX

CONCLUSION

This study has attempted to come to grips with the nature of computing environments in the elementary school through observations and interviews with the component members (students and teachers) as they used computers in four different computer applications. The four computing applications identified and observed were; CAI, programming in BASIC, word processing, and Logo. The data for this study were gathered in May and June of 1984 and therefore particular software being used may not be software used in schools today. I do think it is useful, however, to look back on what was happening at that time. I encourage the reader to reflect on this information in light of current practices. This chapter presents: (1) what each of the four computer applications meant to students and teachers and how this might be interpreted in relation to the theories presented in Chapter Two; (2) my personal description of an autopoietic computing environment; (3) the continuation of my personal history, (4) implications for education brought about by coupling and co-drifting; and (5) suggestions for further research.

THE NATURE OF COMPUTER ENVIRONMENTS

I have chosen to separate CAI into two groups; drill and practice, and problem solving.

CAI - DRILL AND PRACTICE

Students

Anne and Andrew were positive about their CAI experiences on the computer. They both used Milliken Math and both indicated that they liked receiving the rewards. Anne liked the idea that she didn't know what reward was coming next and Andrew felt that students work harder to get to the next level. Through CAI, student work became public and Anne was very concerned that everyone would know when she made an error or needed the computer to help her. She also felt concern that the computer stored information and, with it, errors she had made. The teachers who used this software chose to be in control of what the students practiced as an integrated part of the mathematics curriculum.

The two boys I observed at Queens School found the challenge of the math drill inappropriate and changed it to suit themselves. One boy created the challenge of typing in his answers faster than the computer could react, and the other tried to get the highest number of errors. This was described as "beating the system" by the teacher, but I prefer to think of this as a situation in which the boys felt the activity, as assigned, held no relevance for them.

The social studies unit at Hunter School integrated computer application with the social studies lessons being taught in the class. Many students aimed for mastery, repeating the test several times until they reached a score of 100%. The desire to attain a perfect score can be interpreted in several ways: The child sees some need for the knowledge being learned and wishes to apply it in a different situation; The child doesn't usually have an opportunity to get 100% and uses this as a way to develop self-esteem; The child has parents who expect 100%; The child has high expectations for himself. The behavior observed serves only as a reflection that recursive activity has occurred.

Teachers

The three teachers in Hunter school had varying opinions regarding drill and practice. Mr. Watson was positive about the way CAI was integrated into the classroom curriculum, felt it brought out a "competitive nature", and was motivational. He felt there was good retention of facts with the social studies software. Mrs. Powell was not as positive about the math and social studies CAI. She felt that students socialized too much and that "not that much learning took place." Mr. Cummings felt that there was a movement away from CAI toward teaching children how to access information with computers. Mr. Duncan at Queens school felt that drill and practice on the computer was a novelty and it would wear off if done every day.

Keyboarding done at Hunter school, I feel, would fall into the category of CAI drill and practice. No keyboarding activities were observed as part of this study but Mrs. Powell commented that students enjoyed the activity and that they were motivated to learn to type.

[In the drill and practice computing environments observed, the control was linear, from teacher to computer to student (Fig. 1, p. 95). The input-output computer model describes this environment. The teacher selects the program and inputs it into the machine. The machine outputs it to the student. The student receives questions or information as input, assimilates the information, and outputs an answer to the machine. The process between computer and child repeats itself but notice the teacher is no longer needed to sustain the system. Competition, external rewards, and the presence of a waiting computer help maintain student interest.

During CAI drill and practice, the student, for the most part, was tightly controlled by the software but students did occasionally assume control. Anne assumed control when she rejected the attempt of the software to foster recursive thinking by helping her when she made mistakes. The boys at Queens School, described as "beating the system," assumed control and constructed boundaries around the intended learning. They created a new environment in which they maintained their autopoiesis.

There seemed to be a rigidity in the way teachers used drill and practice, having all students participate in somewhat like an assembly line. Perhaps this environment better supports the autopoiesis of a teacher who feels responsibility to the curriculum and a need to control student behavior.]

CAI - PROBLEM SOLVING

Students

The problem solving software observed in this study was "Thinking with Ink" and "Rocky's Boots". Student reaction to these programs was very positive. Students considered these programs more like "games" and competition did seem to be a factor. Student success on "Thinking with Ink" became very public with names and scores of the top ten players being stored on the disk for future players to see. With "Rocky's Boots", students were guided through a series of activities, receiving rewards along the way, which led toward an open-ended activity of building their own machine. The computer determined if the child's machine would work and then if it would, rewarded the child.

Teachers

Both Mr. Watson and Mrs. Powell were positive toward the use of problem solving CAI software. They were impressed with the open-ended activity of Rocky's Boots.

[This CAI problem solving environment like drill and practice contained only computer (with software) and students (Fig. 2, p. 95). Teachers appeared as "managers" who controlled how the students used the software. The structure of this computing environment was less constraining to the student than CAI drill and practice due to the flexibility of the software. The competition of Thinking With Ink was very motivational for the children who felt they had the chance to see their name "up in lights". This software did not require a specific answer. Recursion could occur if the child returned to the program to try to get a higher score. Rocky's Boots encouraged students to move beyond the assimilation of facts toward the building of a machine. If the machine didn't work the perturbed child could review the steps to gain a deeper understanding.]

COMPUTER LITERACY - PROGRAMMING IN BASIC

Students

The child in a computing environment learning BASIC sees himself as controlling the computer. Actually the teacher is helping the child control the computer. Students were enthusiastic and often persistent, taking several weeks to solve a problem. When they reached a solution there was a mixture of pride and excitement as they wanted to show their work to the teacher and their peers. They truly felt the emotion Polya described as "the most vital point" of the problem solving process (Polya, 1957, p.94). Students at Queens School worked with partners and spoke positively about collaborative learning but some of these students remained in competition with other partners in the class to see who could solve the problem first.

Teachers

Some may consider programming in BASIC open-ended problem solving, but the teachers in the study seemed to include programming in BASIC within the classification "Computer Literacy." Mr. Locke, Mr. Duncan, and Mr. Moore, the three settings in which BASIC was part of the program, all referred to their programs as Computer Literacy. In this computing environment, direct teaching of the commands was a consistent approach. Mr. Locke used high resolution and low resolution graphics to provide his students with a general picture of how computers are programmed. Then students continued to learn BASIC or Logo from worksheets made available by Mr. Locke. Mr. Locke indicated that his students weren't advanced but they had gone through the "first five or six steps" in programming with BASIC. Mr. Locke had expertise in BASIC and the fact that only one of his students chose to do Logo may support teacher direction as being determinative when exploring BASIC. Scott's statement that students learn more about computers at school because, "you're being taught to use it and at home you probably would be working out of a book or what you discover on your own," also supports learning through teacher direction.

Mr. Duncan's method of introducing BASIC supports teacher directed learning. He first had his students explore the preprogrammed graphics and then introduced some BASIC programming which the students were trying to apply at the time of my visits. He stated that at the "initial stages of computer literacy (learning BASIC) it is exhausting because it is continual output until they get used to the idea of seeing what they can do and start to think."

Mr. Moore said, "It takes quite a while to get to the point of being able to solve problems with the computer. Mr. Moore was perturbed by the difficulty his students had trying to solve mathematical problems with BASIC. At the time of my observation, he was having them create high resolution "string" designs and felt that his students were being much more successful. He felt that with the graphic assignment his students had something "visual to connect to right away" and as a result they could evaluate their thinking. This he felt helped them persist long enough to get the final solution.

[The computing environments in this study which used BASIC to teach programming, had a structure in which the teacher was the vehicle through which the child learned to communicate with the computer (Fig. 3, p. 95). Problem solving is a recursive process but because the problems were difficult, the children relied on the assistance of the teacher. Third-order coupling between teacher and student was constrained by the difficulty of the programming language. It did not appear that students were able to initiate their own problems except for graphics and some students did not see graphics as an area which required much thinking. For the most part, the teacher controlled the problems which the students would attempt to solve. Learning BASIC is a structured process with little flexibility in the way programs can be written. Is it the nature of the BASIC language which controls the teacher and therefore the student? When the students have learned enough commands to initiate their own problems or if they stay within the graphics mode, the role of the teacher could change to become that of an aide.]

WORD PROCESSING ENVIRONMENT

Students

In the word processing environment, the child is engaged in the writing process with the computer being used by the child as a tool for that process. This environment is qualitatively different from the CAI and BASIC environments above because the locus of control moves from the computer to the child. Children in the study valued the computer as a word processor. Andrew at Hunter School stated, "If you have to change a lot of it, you can easily change it with the computer. You probably make a lot of changes on it because you know it is easier." Similarly Scott at Riverview School said, "You can learn how to write things easier and correct them easier. It's neater and if you want to change something you can just go to the program and make the corrections and print it out." Students thought that using the word processor for writing involved a high level of thinking. They recognized that writing was the result of thought processes for which they were responsible.

Teachers

All teachers involved with word processing were positive of the results. Mr. Sullivan of Mayridge School saw word processing as being a microworld or an environment where children "can play around with ideas." Mrs. Powell commented that word processing needs a lot of input from the teacher because it is creative. This presented problems for Mrs. Powell because the computers were housed in a separate room some distance away from the classroom. Mr. Watson was optimistic that computers could have a positive effect on writing. He felt that in the future teachers and students may be able to "concentrate on research and functional and creative writing rather than just getting things down legibly on paper."

[The structure of the word processing system was student and teacher communicating about the writing process with the computer facilitating the communication (Fig. 4, p. 95). The computer became involved in this system to the extent that ideas shared during third-order coupling between teacher and student could be facilitated through computer technology. The writing process is recursive and as children interact with teachers about their writing they are able to assimilate the input given. Through a recursive process, inputs become perturbations to which the child makes accommodations and moves to higher levels of organization. The student is in control of the writing and may also control what is to be written about. Mrs. Powell was perturbed by the physical distance between herself and her students during word processing because she felt the writing process is "creative" and needs a lot of teacher "input." Publishing becomes easier and as children enjoy sharing an attractive product, the computer enhances the writing process. The word processing system becomes an autopoietic system when there is an underlying recursive interdependence of the systems components (coherence).]

LOGO

Students

In the Logo environments, control of the learning experience was firmly in the hands of the students. At Mayridge School, Elizabeth and Amanda shared a problem solving experience (of their own chosing) independent of the other members of the class and with very little teacher contact. The decisions they made were truly their own as they considered and rejected suggestions made by myself and Mr. Murphy. When difficulties arose they felt were beyond their control, they modified the problem and continued along a different path. Elizabeth and Amanda found the Logo computing setting "relaxing" and non-competitive where time restraints were not a problem.

At Eastside School students were consulted regarding the structure of the class. They were encouraged to work together and share ideas, but individual digressions were also supported. Bryan seemed to be particular about the appearance of shapes and would go off on "tangents" taking Mrs. Preston and the rest of the class along with him. Sue consulted Mrs. Preston but chose not to use the method they worked out together. The discussion between Sue and Mrs. Preston probably triggered another idea which seemed more relevant to Sue. Cory wanted to restrict discussion and maintain personal ownership of all his projects. Although this was not the atmosphere of the class or the way the other students functioned in this environment, the flexibility of the environment supported his needs.

The Logo environments supported collaborative learning. At Eastside School, all students were working on the same problems, but they each had access to a computer. Although Bryan preferred to work "solo" in the classroom, he recognized the value of sharing a problem in the Logo setting so that the students could "help each other." Sue started off on her own but when difficulties arose, she teamed with a friend. Although Cory was a member of the larger system of the enrichment group which was collaboratively solving the same problems, he wished to remain independent. Within this environment, he was allowed to follow his own path. At Mayridge School, students were encouraged to work in groups of as many as four students but Mr. Sullivan recognized that how the students came to think about the problem could cause the groups to splinter. Elizabeth and Amanda worked together at one computer and were described by Mr. Sullivan as having accepted a "kind of notion of community of learners."

Students were persistent in their efforts to solve problems. Elizabeth and Amanda said it was "a way to learn to try more and not to give up." In the observed settings, Logo activities were almost entirely graphics oriented. Each time the children "tested out" their ideas, they received a graphic reflection of their thoughts. The difference between the image on the screen and the image expected gave clues which the children used to reformulate their thoughts and produce another result. At times the unexpected images became exciting learning opportunities. Students generally agreed that Logo required considerable thinking.

Logo appears to be a good experience for both high and low achieving students. At Eastside School, Logo was offered to the enrichment students. At Riverview School a single "low" student was proud of his accomplishments with Logo. At Mayridge, the most interested students were the two highest and the two lowest.

Teachers

Mrs. Preston felt her role as a teacher was different in the Logo environment because she didn't have a structured method of presentation. All commands were taught incidentally as they were needed. What happened one day would determine what would happen the next. "They are determined to go their own direction." Mr. Sullivan felt Logo provided the opportunity for students to develop "modular or procedural thinking". To encourage this thinking, he felt part of his role as teacher was to present to students project ideas which could be broken down.

[The structure of the Logo computing environment is an integrated system of teacher, student, and computer software (Fig. 5, p. 95). As in word processing, a coherence exists between teacher and student beyond the computer as they engage in recursive conversation about Logo. For example, coherence exists when the child and teacher become involved in "playing turtle" on the classroom floor. The recursive nature of the Logo language encourages recursion and reflection with the component members (teacher and students). Through the circularity of the reflection/recursion/reflection process, a coherence develops between Logo and the component members. As these coherent systems enter the niche of the other they become cross-perturbational encouraging further recursion and reflection. These recursive processes can be cross-perturbational to other members of the classroom and thus encourage a spontaneous social system which supports the autopoiesis of the component members. For example, Bryan's recursion with Logo resulted in his desire to fill a square and make a realistic chicken. This was perturbational to Mrs. Preston and to other members of the class as they went on a "little side trip". The community became involved with Bryan's perturbation.

There were several examples of the Logo environment being a community of learners. At Eastside School, the atmosphere of the enrichment class was one of student/student and student/teacher collaboration. At Mayridge school, Elizabeth and Amanda were cross-perturbational in the absence of Mr. Sullivan. The girls appeared to work independent of the teacher, but they came to the setting with ontogenies which included the recurrent presence of Mr. Sullivan. Mr. Murphy said that the students were getting bored with Logo because they had to tutor one another. This further supports the structure of this environment as an integrated system of student (or students), teacher and computer. For some students in this class, removing part of the structure (Mr. Sullivan), proved to be destructive to the system, while Elizabeth and Amanda, perhaps because of their collaborative efforts, were able to continue.

The boundaries of the Logo language provide constraints but the simplicity of the language allows the flexibility for the children to solve problems in many different ways. Mrs. Preston said, "they are determined to go their own way." Often teachers initiate problems, but the children assume control of the process, modifying or digressing as desired. The children often initiate involvement of the teacher, but because the children control the direction the problem solving process takes, the teacher must try to fit into the cognitive domain of the child in order to build the bridge from the child to the computing language and from the computing language to the child. A computing system emerges in which all subsystems of this social system form a community as they engage in "conversation" with one another.]

THE AUTOPOIETIC COMPUTER ENVIRONMENT

The computing environments above have emerged spontaneously as a network of component members (student/s, teacher, and computer) engaged in third-order coupling. A computer, however, is not a living system and therefore cannot, in itself, be autopoietic. However, its structure, through use of software and computing languages may simulate a living system, in that communication can take place between the computer and the living components of the social system (student/s and teacher). This social system then contains two or more living subsystems which can be cross-perturbational and adaptive in their structure while communicating with computer (software) which can be changed by one of the members.

All members of the computing environment (student/s, teacher, and computer) are products of their past. Teachers' views of education are compositions of previous and current third-order coupling experiences. Teachers' ontogenies develop from their membership in subsystems of other social systems (i.e., school, school district, and so on). The personal structure teachers bring to the computing environment are products of their ontogenies. For example, Mr. Duncan viewed marks as motivational incentives to learning.

Students are products of their personal histories. Children tend to want to see themselves as grown up and to imitate adult behavior. Several children in the study were pleased because they were able to do something with computers which their parents didn't know how to do.

Computers come to the computing environment not with a personal ontogeny but with a history of relationships involving other living systems (programmers and technicians) and with a structure that can be changed by the other members of the computer environment.

Within the theory of autopoiesis, the ideal educational computer environment would be one in which all subsystems engage in autopoiesis which is made richer by the cross-perturbations between the subsystems. I suggest that the Logo environment (Fig. 5) can be an ideal educational computing environment. In the Logo environment, there is a coherence between all component subsystems as they engage in third-order coupling, proceeding in a co-ontogenic structural drift. Is Logo a necessary requirement before students, teacher, and computer in third-order coupling can co-drift? No, Logo is simply technology to enhance cross-perturbations that disrupt the equilibrium of the the system and its components pushing them recurrently toward states far-from-equilibrium.

Drill and practice can be a form of recursion contributing to the maintenance of the cognitive domain of students. In this sense, drill and practice software, in itself, is not problematic. I contend that it is possible to adapt the CAI computing environments (Fig. 1 and Fig. 2) described in the study to become autopoietic computing environments. Three major shifts must be made; the teacher must be in perturbatory communication with the child, control must move from the computer to the child, and competition must not play a major role. Students, through communication with the teacher, should be involved in their learning so that they can identify what they need to learn. Drill and practice could be made available as one of several alternatives for maintaining what they know they need to know. As the children make decisions about what software they will use, they become more cognizant of their own processes of production and uses them to organize their own learning. CAI software can be used to encourage collaborative rather than competitive relationships among students. For example, groups of students could try to solve "Thinking with Ink" with multiple copies of the program so that they would all have their "names up in lights".

The computing environment which focuses on BASIC can become an autopoietic computing environment "somewhere further down the road". The problem solving relationship (using BASIC) which the teacher would share with a student in an autopoietic computing environment has a difficult time emerging in the elementary school. Perhaps this is why both Mr. Locke and his student Brent mentioned student success in junior high. In contrast, all teachers in the study seemed positive about elementary students doing graphics in BASIC. Did the teachers sense that children writing graphics programs were more in control of their learning (autopoietic learners)?

In the word processing environment, the student and teacher are in close communication about the writing process. The control of the learning has moved to the student. Mr. Sullivan refers to word processing as a microworld in which students "play around with ideas". Could it be that Mrs. Powell was perturbed by being physically separated from students as they used word processors because communication between herself and student was constrained? If students must go to a different area to use computers, communication could be enhanced if the teacher enters comments into the text written by the child. Word processing should be part of the ongoing writing process within the classroom.

The significance of communication can be appreciated in realizing that an autopoietic computer environment supports collaborative learning. This may be student/teacher or student/student collaboration with recurrent communicative support from the teacher. In this way, the autopoiesis of the computing environment depends upon all components of that environment, but teachers are particularly significant participants who can modify seemingly allopoietic learning environments so they become autopoietic.

CONTINUATION OF MY PERSONAL HISTORY

The introduction of microcomputers disrupted the equilibrium of my classroom and during my study I was encouraged by observing other teachers similarly in states of disequilibrium. Prior to the study I knew "something" was happening to my students and myself. Prigogine's Theory of Dissipative Structures and Maturana's and Varela's Theory of Autopoiesis provided me with the language to discuss what that "something" was and assisted in the description of the computing environments I visited.

Perturbations triggered recursive thinking beyond the computer setting and when I returned to my grade four class in September of 1984, I was excited about trying to implement some changes within my classroom. I wanted desperately to create for my students a learning environment which would support their autopoiesis. Mr. Sullivan aptly called this a "community of learners".

During the four school terms which have passed since gathering the data, I have maintained a commitment to encourage a feeling of "community of learners" among students within my classroom. I have been fortunate to engage in exciting third-order coupling relationships with teachers and staff members within my school which have assisted me in that process. These third-order coupling relationships have often been cross-perturbational resulting in co-drifting. For example, one of the teachers on my staff, a language arts/reading specialist, became a person with whom I could discuss "whole language". The philosophy of whole language seemed appropriate for my classroom but my experience with language arts had been the teaching of segmented skills. I relied on the availability of a coupling relationship to assist with implementation. She, on the other hand, had no experience with computers. She now has a computer at home and insists that a computer be part of her classroom.

The system within the classroom begins to grow the first day of school. Themes, into which curriculum areas are integrated, provide a platform upon which learning activities are built. Activities are planned to encourage recursive thinking. I see my role as a teacher to help students build bridges between what they know and what they want to learn. Hopefully, well planned learning activities will join together what they want to learn and what the curriculum dictates into an integrated unit.

I try to capitalize on student interest and spontaneity. For example, it's exciting when a student chooses to do research on a science topic related to the "Space" theme, goes to the computer lab to use the word processor to prepare a reading activity to share with the rest of the class in language arts period and the discussion which results focuses on mathematical problems arising from the information; or when a child stands up in the class to explain his "Thingamajig" made from scrap material and it is a specially equipped space station which will replace the depleting ozone in the earth's atmosphere. My classroom may be termed a "substitute's nightmare" as some substitutes feel the need to assume control of the class and find it difficult to fit into the community of the classroom.

Collaborative learning is encouraged within my classroom. Students are encouraged to form spontaneous social systems to further their learning. An atmosphere which encourages collaborative learning should also support collaborative evaluation (student and teacher). Formal evaluation is a constraining feature of the larger social system within which my classroom is embedded. Evaluation of learning encourages reflection and recursion but grading is not a part of this system.

Within my school the "centres room" has grown from collaboration among teachers interested in providing learning centres for their students. This project was initiated by a small group of teachers on staff and through third-order coupling and co-drifting has become a school wide project. Teachers are working collaboratively, sharing ideas and materials in the creation of learning centres. Special education and regular classes have combined in the centres room, with benefits being reciprocal. Students in regular class have the opportunity to confirm their thinking by explaining it to a special education student, and special education students are able to participate more fully in activities with the one-one-assistance of another student. I am excited by the potential of the centres room as it contributes to the development of a "community of learners". Another exciting outcome of the centres room has been the visits from teachers in other schools and other school districts. We are beginning through these visits to establish a communication network to share ideas and materials across schools and across districts.

Computing environments have now expanded far beyond my classroom walls into almost every classroom in the school. Using a limited number of computers with a large number of students creates a far-from-equilibrium situation which may discourage teacher participation. A two year program of implementation began in 1986 - 87. In year one of the program I taught grade one, two, and three classes with the help of a teacher's aide. Teachers of these classes taught my students physical education and art. Occasionally substitutes were brought in and the teachers observed in the lab. In the second year of the program, the teachers assumed responsibility of the computer program, with the assistance of the teacher's aide. The relationship I had with the teacher's aide was truly collaborative. She had never touched a computer but had extensive experience with primary students while my experience with primary students was very limited. Throughout the two year period, I attended a Peer Tutor Project offered by Edmonton Public School Board, Microcomputing Services. Attending this project encouraged me to reflect on how implementation within my school was working.

Computer technology remains an important part of the learning community within my class. Considerable freedom is offered to students regarding computer usage. At times the computer lab becomes an extension of the centres room with activities related to the theme. Some choose to do CAI because its "fun" or in response to a learning need. Word processing is a part of the writing process within the classroom. Logo continues to excite both students and myself as we try to create what they want to create.

At times throughout the past four years, I have felt panic. I've wondered whether I was moving in the right direction or whether the students were learning what they were supposed to learn. It has been the students and their positive reactions to this learning environment which has encouraged and strengthened my commitment.

IMPLICATIONS BEYOND COMPUTING ENVIRONMENTS

Educational systems are concerned with providing learning experiences which will better prepare our students for life in a rapidly changing technological era. Suzanne Baily (1986) suggests that functioning well in the 21st century will require students to be critical thinkers, assume responsibility for their learning, be able to cooperate and collaborate in problem-solving activities, develop a process for managing information and applying it, and be an empowered planner with a rationale for organization (p.57). Partly in response to the requirements above, we have seen movements such as computers, whole language, collaborative learning, and learning centres widely discussed in educational circles. Change can occur as members of subsystems couple, gain momentum, and move away from equilibrium, re-couple and move again in repeated instances of co-drifting. Personally my experiences with computing and questioning of my teaching practices have lead to exciting and rich coupling relationships with other teachers, within the computing community and beyond. Change among component members can lead to change in the larger social system. As teachers are the basic components of the educational social system, it may be wise to facilitate collaboration or coupling among teachers and among teachers and university professors as a way of constructing autopoietic third-order systems that are enhanced by and enhance the autopoiesis of all components.

SUGGESTIONS FOR FURTHER RESEARCH

Application of the biological metaphor of autopoiesis to the educational setting is relatively new. Ideas for further research may be:

1. to use the biological metaphor of autopoiesis to discuss other ethnographic research in the schools;

2. to investigate autonomy of students in computing environments and beyond;

3. to study how inservice of teachers happens within the school;

4. study interaction between component members of a system at a learning centre;

5. study collaboration between students, teachers, student teachers and cooperating teachers, etc.

COMPUTING ENVIRONMENTS IN THE ELEMENTARY SCHOOL

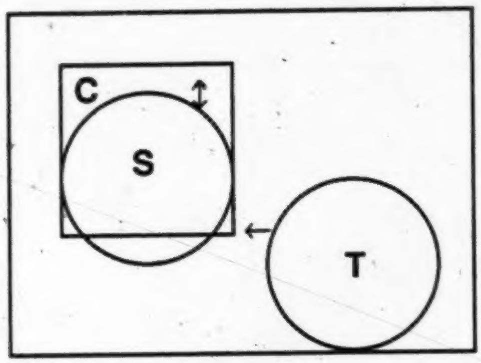

FIG. 1 CAI Drill and Practise

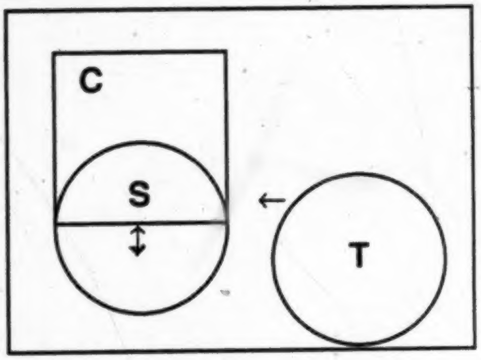

FIG. 2 CAI Problem-solving

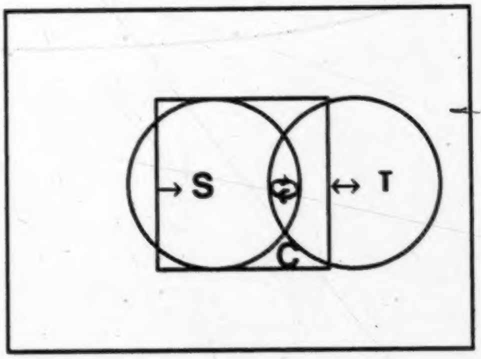

FIG. 3 Programming in BASIC

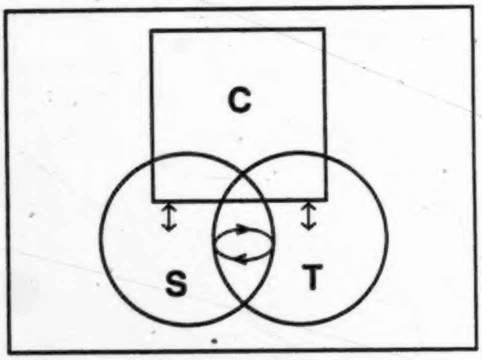

FIG. 4 Word Processing

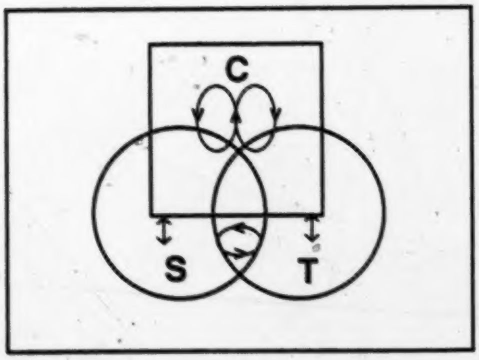

FIG. 5 Logo

→ - INPUT

⟲ - COHERENCE

C - COMPUTER

Ⓢ - STUDENT

Ⓣ - TEACHER

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APPENDIX
GLOSSARY

adaptation
structural transformation of a living system while maintaining the unity of the system

allopoietic system
a non-autonomous system which has a feedback mechanism through which information is received and transmitted through apparent inputs and outputs

autopoiesis
{derived from autonomous, and "poiesis", meaning self-creation or self-production} the process of living systems (unicellular systems to complex social systems) which autonomously maintains or conserves the unity of the system.

bifurcation point
point at which a system, which is in a state far-from-equilbrium with the environment, restructures itself or disintegrates

communication
the behavioral coordination which occurs during social coupling

dissipative structures
levels of organization which emerge spontaneously as open systems reorganize in response to being in a state far-from-equilibrium with the environment

entropy
energy lost during irreversible transformations; degradation of energy

input
non-perturbational disruptions from the environment to which the system responds

invariant qualities
those qualities left unaffected by perturbations; the essence of the living system

natural drift
structural changes to both living systems and the environment in response to mutual perturbations

ontogeny
history of structural changes of a living system

organization of a system
the set of relations that must exist among the components of a system for it to be a member of a specific class (Maturana & Varela, 1987), i.e., computer, ape, cat (see also, structure of a system)

phylogeny
structural transformations maintained by the organism through reproduction; evolution

perturbation
interactions which trigger changes in the equilibrium of the system. Perturbations may be generated by the environment or by the system itself and cannot be interpretted as good or bad.

recursion
"a process which operates on the product of its own operation" (Maturana & Varela, 1987, p. 253).

reflection
product of recursive processes, as well as, the process of maintaining the unity of the system throughout recursive interaction (Sawada & Olson, in preparation)

structural coupling
the process of living systems linking or connecting with their environment. There are three orders of structrual coupling: (1) first-order coupling; a unicellular organism couples with the environment, (2) second-order coupling; a metacellular organism, which contains within its structure antonomous living systems, couples with the environment as a distinct unit, (3) third-order coupling or social system; structural coupling within a linquistic domain.

structure of a system
the components and relations among the components that constitute a particular unity, i.e., if the organization of the unity is a computer the structure of that unity would be CPU, keyboard, RAM, monitor, etc. - computers would differ in their structure but be alike in their organization.

third-order coupling
see structural coupling